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AM/AGC COMBINER.(U)

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SAMTEC TR 77-35

AM/AGC COMBINER

FEDERAL ELECTRIC CORPORATION
VANDENBERG AFB, CA 93437

10 FEB 1976

UNLIMITED DISTRIBUTION

PREPARED FOR
SPACE AND MISSILE TEST CENTER
VANDENBERG AFB, CALIF 93437

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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This report presents test results and operational launch support data used to compare the performance of a standard AGC controlled combiner to the performance of a prototype combiner unit which features AM (a quick response envelope detector) and AGC control. Results of test data and launch data indicate that the PMTC "COMB/SEL" combiner with the low pass filter removed from the control circuit provided the best data recovery under launch conditions.

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LIST OF FIGURES

1.0 INTRODUCTION

1.1 This report is published in response to SAMTEC Performance Analysis Task A6141 which directs the test and evaluation of the AM/AGC controlled Combiner Unit Phase III. This report presents information on operational verification test results obtained with a multipath simulation test set and data recorded during missile launch operations.

1.2 The Pacific Missile Test Center (PMTC) responding to a task from the Range Commanders Council Telemetry Group, designed, fabricated and lab tested a circuit that would utilize the AM detected IF signals and AGC voltages from the telemetry receiver for combiner control. The Phase III AM/AGC Combiner Unit which is analyzed herein incorporates modifications from the first and second Performance Analysis Department investigation. "Diversity Combiner AM/AGC Control Technique (Phase I)" 21 Aug, 1975 and "Preliminary Report on the Diversity Combiner AM/AGC Control Technique" (Phase II) 21 Sept 1976 are included as Appendix C and D respectively. A brief description of the AM/AGC Combiner unit is contained in Appendix A.

1.3 The advantage of the AM/AGC unit is the ability of its AM detector to follow rapid radio frequency (RF) carrier amplitude fluctuations which the relatively slow receiver AGC circuitry does not respond to. The purpose of the AM/AGC unit is two-fold; first to provide a control signal that responds to the rapid RF fluctions and second to utilize the control signal to combine two signals with independent amplitude fluctuations.

1.4 Telemetry data recorded during several Minuteman launch operations showed that the PMTC combiner was able to retrieve significantly more data than the normal AGC controlled combiner during rapid fade conditions which occur during third stage burn of the Minuteman III missile. All available data used in this report preparation has been sent to the Pacific Missile Test Center for evaluation.

2.0 OBJECTIVES

2.1 The objectives of the tests and analysis reported herein are:

a. To determine whether or not the AM/AGC Combiner Unit will provide better data acquisition during rapid alternating channel fade conditions.

b. To measure any improvement in data recovery over that of the standard AGC controlled combiner during multipath conditions of a missile launch operation.

c. To determine the limiting performance factor associated with the AM/AGC Combiner Unit.

3.0 TEST AND TEST RESULTS

3.1 Dynamic Alternate Righthand (RH) and Lefthand (LH) Channel Fade Test

3.1.1 With the equipment configured as shown in Figure 1 the control voltages of each function generator output were adjusted to simulate RH and LH channel fading using SAMTEC control voltages. Dynamic test results are shown in Table I. The table shows the dynamic testing with the 100 KHz Low Pass Filter (LPF) only. A component failure occurred before dynamic testing with selected filter bandwidths could be performed.

3.1.2 The next phase of the bench test was to determine how much noise is introduced on the control voltage when the LPF bandwidth is increased. Figure 2 shows an oscilloscope picture of the receiver AGC voltage, a control voltage from the AM/AGC unit with a 100 KHz LPF and a control voltage from the AM/AGC unit with the LPF out of the circuit. The initial test conditions used were: SNR set at 10db, fade rate 20 Hz; and SAMTEC type control voltage used to control alternate channel fades. From Figure 2 it can be seen that the noise introduced on the control voltage with the 100 KHz LPF in the control circuit has a peak to peak amplitude of approximately 140mV and the peak to peak noise on the control voltage without the LPF was approximately 160mV.

3.1.3 A test was performed to measure any delay between the data signal and the control voltage. With the equipment configured as shown in Figure 3 the delay between the combiner control voltage and the data signal was measured. The measurement indicated that there was a delay of approximately 15-20 microseconds between the combiner control voltage and the data signal. That is the control voltage lags the data signal by approximately 15-20 microseconds.

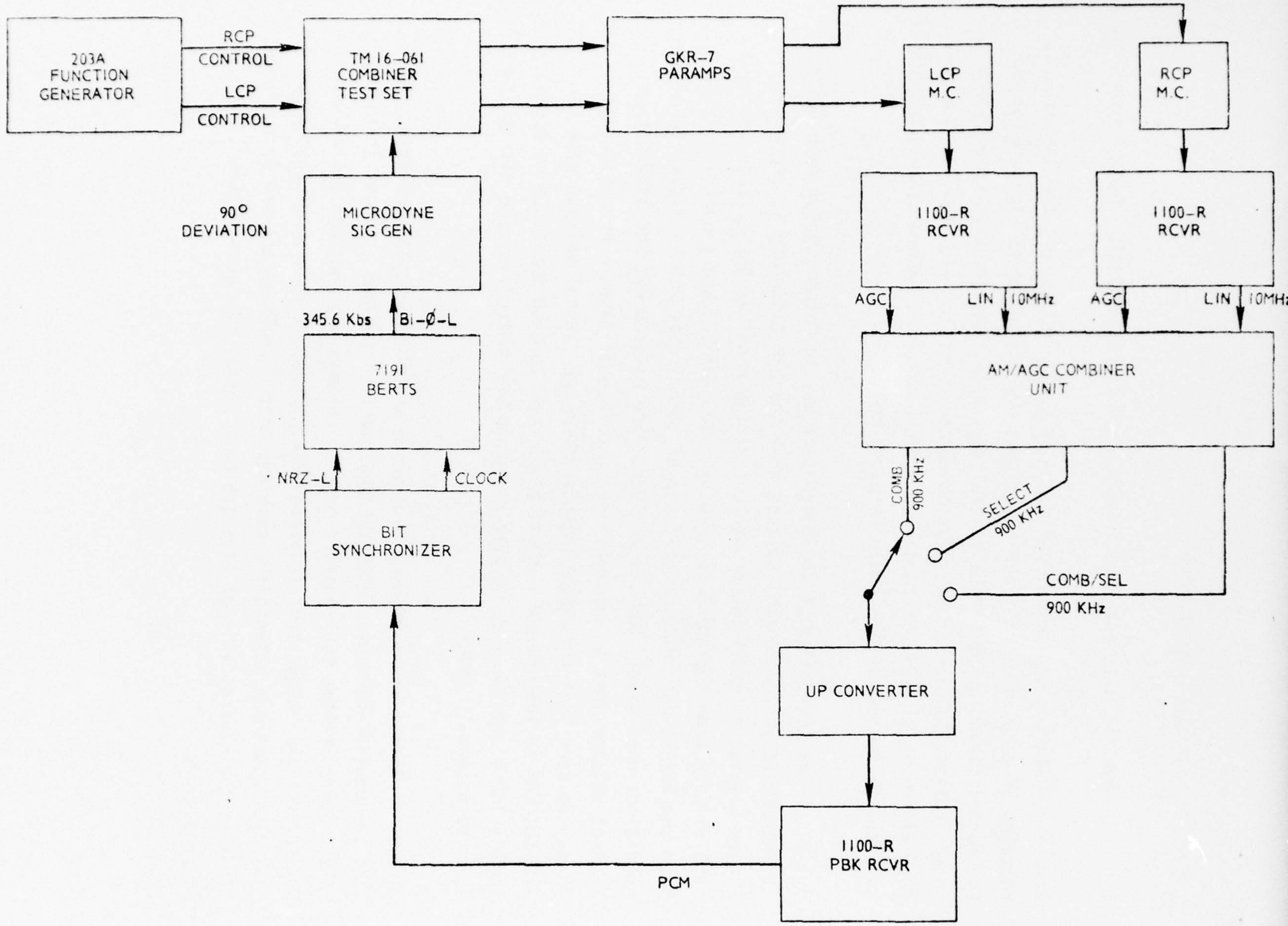


FIGURE 1 OPERATIONAL VERIFICATION TEST CONFIGURATION

Table I

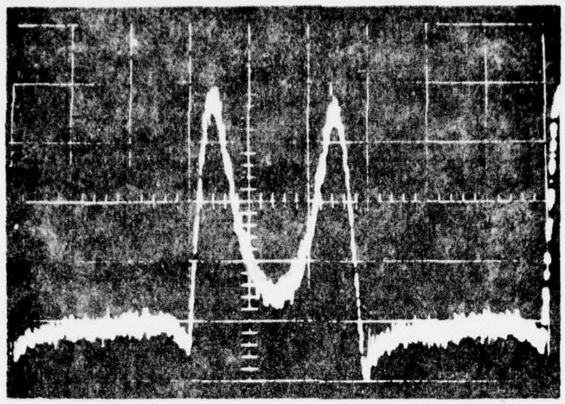
Dynamic Test Results

Combiner Test Set Control Voltage	Combiner	Fade Rate*
SAMTEC	COMB	1450 Hz
SAMTEC	SELECT	.5 Hz
SAMTEC	COMB/SEL	915 Hz
SAMTEC	NORMAL	215 Hz
SAMTEC	COMB	2200 Hz**
SAMTEC	SELECT	N/A
SAMTEC	COMB/SEL	1030 Hz**
SAMTEC	NORMAL	590 **

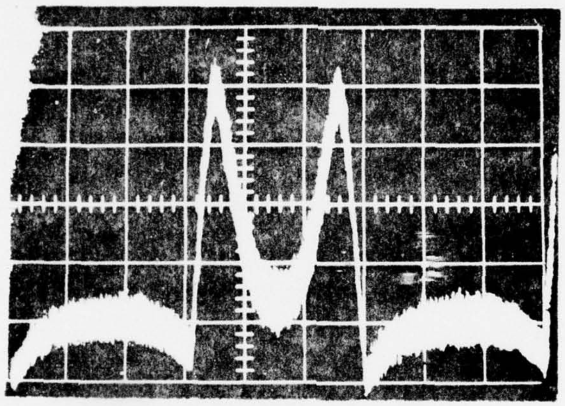
* Fade rate value was the point at which the BER increased by two orders of magnitude.

** These fade rate value were taken when the BER increased by three orders of magnitude.

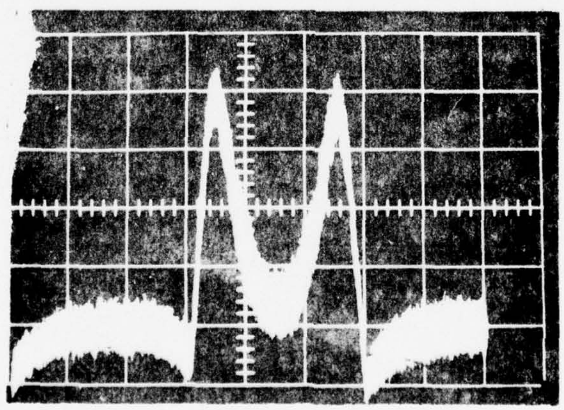
(A.)



(B.)



(C.)



Vertical .2V / cm

Horizontal 10m sec / cm

Figure 2 The Control Voltage (A.) Receiver AGC, (B.) AM / AGC Unit with 100KHz LPF, (C.) AM / AGC with no LPF .

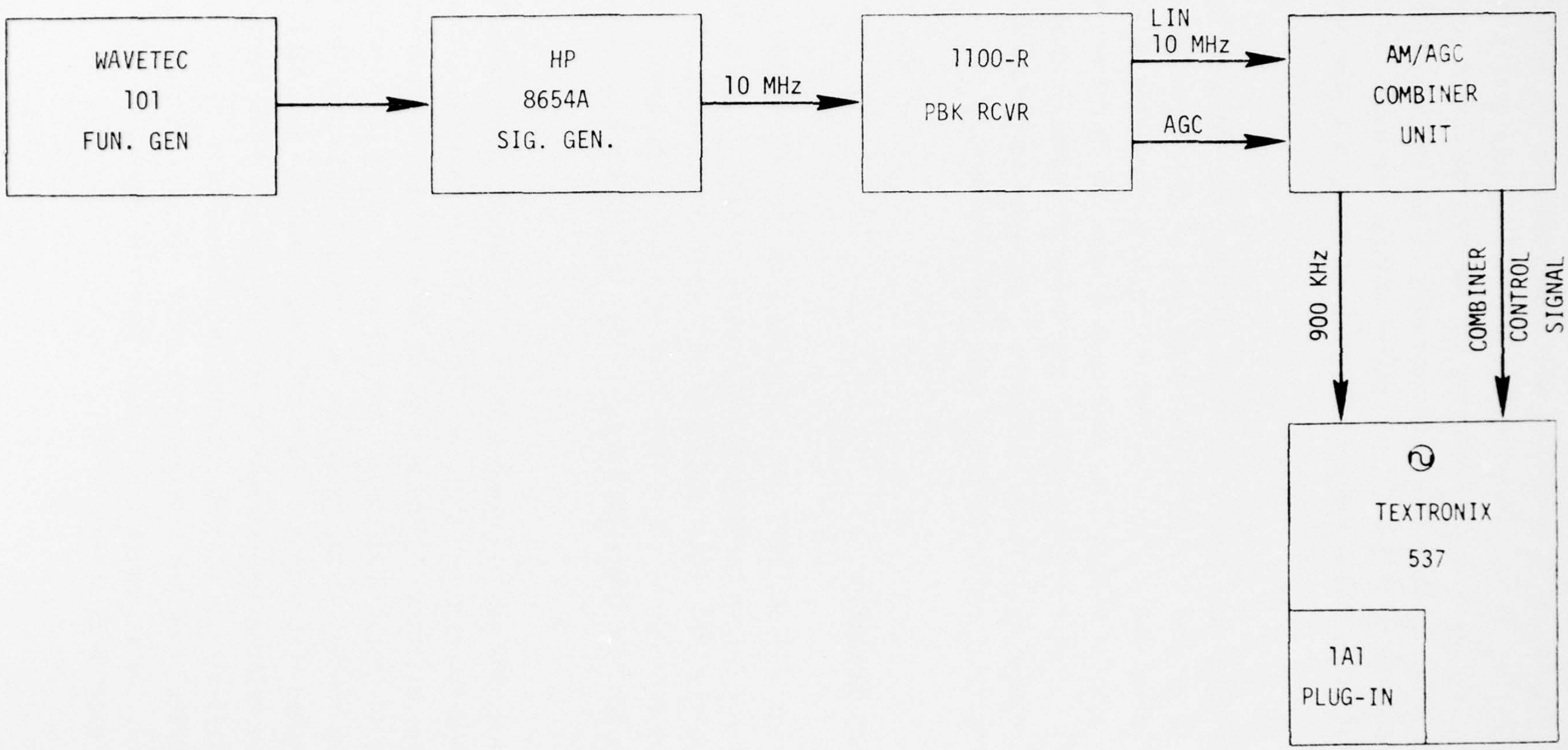


Figure 3 CONFIGURATION SET-UP FOR MEASURING THE DELAY BETWEEN CONTROL SIGNAL AND THE DATA SIGNAL

3.2 Launch Data

Four Minuteman III telemetry operations were supported with the AM/AGC Combiner Unit. This section summarizes the analysis of data quality from two of the missile launch operations using the 100 KHz low pass filter, one missile launch operation using a 250 KHz low pass filter and one missile launch operation with no filter in the control voltage circuit. The set-up procedures established by PMTC personnel were used for each launch operation support.

The Minuteman booster data format is PCM/PM, Bi-Ø-L. The PCM frame synchronization (FS) is 27 bits long at a repetition rate of 30 milliseconds. The word synchronization (WS) pattern is 3 bits long at a repetition rate of 78 microseconds. Special software was developed to scan the FS pattern and WS patterns. This software program counted the number of frames scanned and gave the total number of FS patterns in error, the total number of WS patterns in error and the total number of frames which had WS errors.

3.2.1 Launch Operations

Launch Operations 6995 and 1160 were supported with the PMTC AM/AGC combiners and with a 100 KHz LPF in series with the control circuit. Except for lift-off and staging the PMTC "COMB" and "COMB/SEL" combiners consistently provided more error free data during third stage burn relative to the normal combiner. Data summaries for both operations are provided in Appendix B on pages B-2 through B-25.

Launch Operation 5649 was supported with the PMTC AM/AGC Combiner Unit. The only support modification was that the 100 KHz LPF was replaced with a 250 KHz LPF. The change was made to find out if the added noise on the control signal due to the increased bandwidth of the LPF would effect the combiners decision-making process during multipath conditions. Post operation analysis of the data showed that with the wider LPF, the "COMB/SEL" and "SELECT" combiners provided a relative improvement in data acquisition. The improvement was noted during lift-off and staging. During third stage burn the data showed that the "COMB/SEL" combiner provided more error free data relative to the normal combiner. Data summaries for Launch Operation 5649 are included in Appendix B on pages B-26 through B-34.

Launch Operation 8741 was supported with the PMTC AM/AGC Combiner Unit. For this launch support the LPF cutoff frequency was approximately the bandwidth of the operational amplifier (~ 10 MHz). Post operation analysis shows a significant improvement in data acquisition at lift-off, staging and during third stage burn periods. Data summaries for Launch Operations 5649 are included in Appendix B on pages B-26 through B-49.

The analysis of the four operations indicates that the PMTC "COMB" during lift-off and staging is combining the good data with the bad data or noise. This also is the basic problem during third stage burn. If the SNR of both input channels was above noise (0db) the "COMB" output would be the best selection for a combiner. The PMTC "SELECT" combiner works best during transients where a rapid channel selection is necessary, e.g. staging, where the signal goes to noise. The select function will select the input channel with the highest SNR to maintain the longest data interval before noise and at acquisition will select the first channel received. The PMTC "COMB/SEL" combiner uses the best of the "COMB" function and the "SELECT" function. Analysis shows that with the LPF removed from the control circuit, the "COMB/SEL" combiner provided more error free data than either the "SELECT", "COMB" or the Microdyne combiners. Because only one operation was supported using the PMTC AM/AGC unit with the LPF removed from the control circuit further testing on launch operations to provide a reliability and repeatability background should be accomplished. Table III shows the performance of each combiner for all four launches.

TABLE III

COMBINER PERFORMANCE DATA QUALITY

OP NO	COMBINER	FILTER	L/O*	I-II* STAGING	III* STAGE
6995	PMTC "COMB"	100 KHz	4.99%	1.85%	0.16%
6995	PMTC "COMB/SEL"	100 KHz	3.06%	1.73%	0.23%
6995	PMTC "SELECT"	100 KHz	3.77%	1.77%	1.67%
6995	NORMAL	N/A	1.34%	1.54%	0.46%
1160	PMTC "COMB"	100 KHz	.95%	1.96%	0.24%
1160	PMTC "COMB/SEL"	100 KHz	4.37%	2.01%	0.17%
1160	PMTC "SELECT"	100 KHz	1.72%	2.66%	0.60%
1160	NORMAL	N/A	1.57%	1.96%	0.27%
5649	PMTC "COMB"	250 KHz	+	+	+
5649	PMTC"COMB/SEL"	250 KHz	.83%	1.73%	0.72%
5649	PMTC "SELECT"	250 KHz	.52%	2.01%	0.92%
5649	NORMAL	250 KHz	.54%	1.73%	1.10%
8741	PMTC "COMB"	**	.44%	2.1%	.58%
8741	PMTC "COMB/SEL"	**	.04%	.86%	.09%
8741	PMTC "SELECT"	**	4.60%	N/A	.07%
8741	NORMAL	N/A	.05%	.86%	.277%

* Percent of word sync error.

** For this OP the LPF was not used.

\+ Because of a set-up problem the"COMB" performance was degraded.

4.0 CONCLUSIONS

4.1 Dynamic test results showed that the PMTC AM/AGC combiner is approximately 4 times faster than the Microdyne AGC controlled combiner and the PMTC "COMB/SEL" combiner is twice as fast. Testing was done using 100 KHz LPF only. A problem had developed which could not be resolved before the PMTC AM/AGC combiner was to be returned. Therefore testing using various LPF could not be performed.

4.2 A comparison of noise on the control voltage with a 100 KHz LPF and without a LPF showed there is very little difference in peak to peak amplitude. The average peak to peak difference is approximately .02 volts. This small increase of noise on the control voltage should not adversely affect the decision making of the combiner.

4.3 It was found that the control signal lags the data signal by approximately 15-20 microseconds. This delay can cause combiner selection to be degraded at low SNR where channel selection is most critical.

4.4 Analysis of operational launch data indicates that both PMTC "COMB" and "COMB/SEL" combiners provided more error free data than the AGC controlled Microdyne combiner with the 100 KHz and 250 KHz LPF during third stage burn. The PMTC "COMB/SEL" combiner with the LPF removed from the control circuit was exceptional during lift-off, staging, and third stage burn.

5.0 RECOMMENDATIONS

5.1 The phase detector circuitry in the "COMB/SEL" circuitry should be made to select when the phase difference between channels is $\leq 60°$ and not 90°. The threshold at which switching should start should be set so when the SNR is approximately 8-9 dB the select circuit will override the combine voltage.

5.2 A delay line should be installed between the downconverter and the combiner to match the delay of the combiner control signal.

5.3 Delete the "SELECT" combiner and add in its place a combiner that operates similarly to the "COMB/SEL" combiner, however, at threshold rather than depend on phase difference as a decision making source, use the comparator circuit to select the highest channel. This would provide two combiners that would operate in the Combine/Select mode. Except, when in the threshold region one select function would compare SNR and the other would compare phase difference.

5.4 Further testing of the PMTC AM/AGC combiner unit should be made to establish an optimal LPF for the combiner control circuit as well as reliability and repeatability data. These test results can be used for specifications for any further modifications or purchases of receivers and combiners to support new programs and/or requirements such as the MX program.

APPENDIX A

AM/AGC COMBINER PHASE III

The Phase II test results showed that the phase lock loop (PLL) noise bandwidth in the Microdyne 3300C combiner was too narrow to maintain phase lock during fast signal null transitions. The phase III modification consists of a prototype phase lock loop with a wider noise bandwidth and a combiner.

Figure 1 shows a basic block diagram of a combiner. This diagram will help describe how the PMTC AM/AGC combiner works. The lefthand (LH) and righthand (RH) 10 MHz linear IF receiver signal is provided to the PMTC combiner from a Microdyne receiver. This signal goes through a power divider (PD). The output of the PD goes to a fast AM detector and to a downconverter. The downconverted RF and LH signal goes to the combiner. The combiner combines the signal based on the control signal.

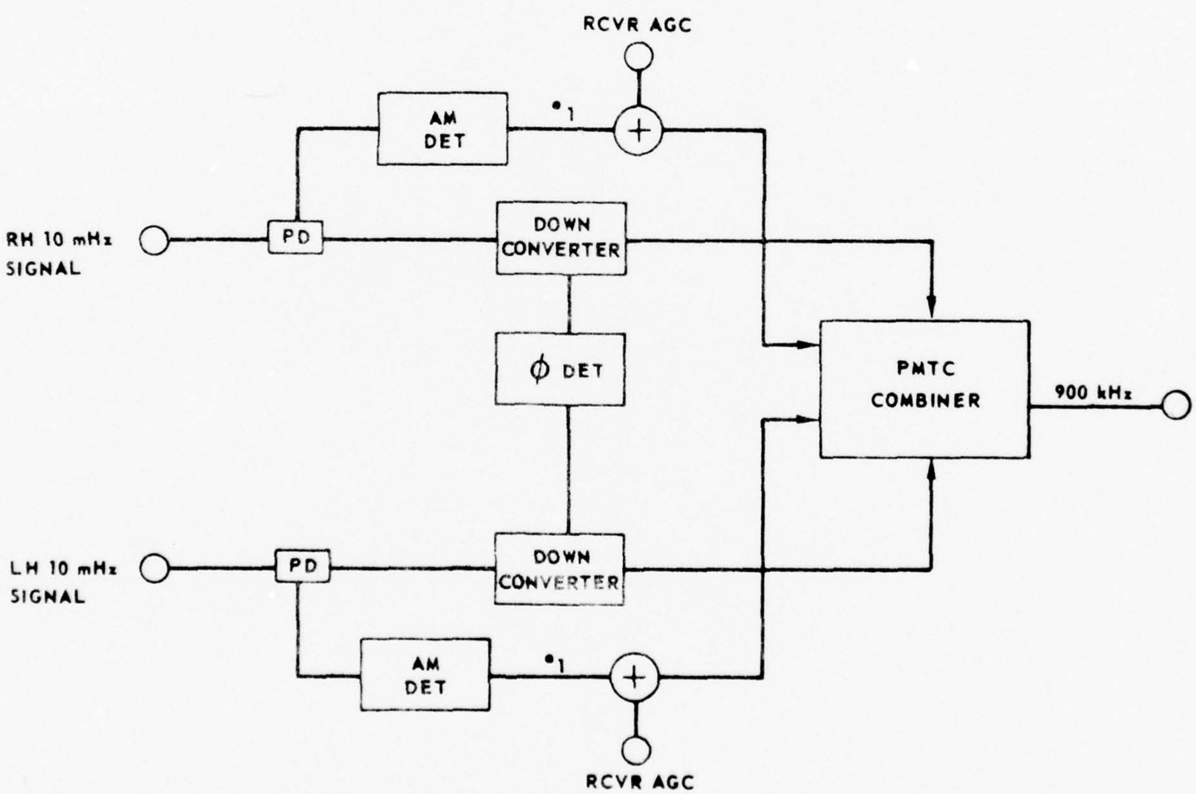


FIGURE 1 BLOCK DIAGRAM OF A COMBINER

The PMTC combiner control signal is developed from the fast AM detector which follows fast RF null transitions. The output of the AM detector goes through a low pass filter (100 kHz) and to a logarithmic amplifier. This signal is then summed with the Microdyne receiver AGC providing a fast combiner control signal to the combiner.

The PMTC downconverter consists of a phase lock loop with a wide noise bandwidth (10 kHz). The wide noise bandwidth was to provide better tracking during fast signal nulls. The downconverter translates the 10 MHz receiver IF signal to a record frequency of 900 kHz.

The PMTC AM/AGC unit consists of three combiners. Each combiner is controlled by different control voltages. The "COMB" combiner used the signal developed by the sum of the log of the AM detector output and receiver AGC voltage for optimal ratio combining. The "Select" combiner uses the same control signals that is used to control the "COMB" combiner. This control signal goes to a fast comparator. The comparator compares the RH and LH control signals and provides a square wave output. The output controls the "SELECT" combiner. The comparator switches when there is a 6 db signal difference between channels and will select the highest signal channel. The "SELECT" combiner does not do ratio combining but "hard" selects the channel with the highest signal. The "COMB/SEL" uses the same control signals which controls the "COMB" combiner plus another control signal which is developed by a phase detector. The "COMB/SEL" combiner operates as a ratio combiner when the phase angle difference of both the RH and LH signals are less then 90°. When the phase angle difference of the RH and LH signal exceed 90° the channel with the highest SNR will be selected and held till the signal phase angle of that channel goes below 60° at which point the "COMB/SEL" combiner will then operate as a ratio combiner.

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APPENDIX B

WORD SYNC. ERROR DATA

SUMMARY

TAPE NUMBER [illegible]216 — DP 6995 "COMB" — STARTING TIME 30006.6730

TIME INTERVAL 1 — STOPPING TIME 30010.6730

THERE WERE 133 RECORDS SCANED IN THIS
TIME INTERVAL OF WHICH 23 CONTAINED
WORD SYNC ERRORS.
THERE WERE A TOTAL OF 2537. WORDS IN
ERROR AND 17 FRAME SYNC ERRORS DURING
THIS TIME INTERVAL.

B-2

WS ERRORS DURING LIFT-OFF

191331

-----SUMMARY-----

TAPE NUMBER 1 225 — STARTING TIME 30006.6730

TIME INTERVAL 1 — STOPING TIME 30010.6730

OP 6995 "COMB/SEL"

THERE WERE 123 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 23 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1562. WORDS IN ERROR AND 15 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

B-3

WS ERRORS DURING LIFT-OFF

-SUMMARY-

TAPE NUMBER 13339 STARTING TIME 30006.6730

TIME INTERVAL 1 STOPING TIME 30010.6730

OP 6995 "NORMAL"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 15 CONTAINED ~~WORD SYNC ERRORS.~~

THERE WERE A TOTAL OF 683. WORDS IN ERROR AND 11 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

B-4

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 14390 STARTING TIME 30007.0000

TIME INTERVAL 1 STOPING TIME 30011.0000

OP 6995 "SELECT"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 33 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1926. WORDS IN ERROR AND 24 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 10215 STARTING TIME 30065.1330

TIME INTERVAL 2 STOPING TIME 30069.1330

DP 6996 "COMB"

THERE WERE 133 RECORDS SCANED IN THIS
TIME INTERVAL OF WHICH 4 CONTAINED
WORD SYNC ERRORS.

THERE WERE A TOTAL OF 945. WORDS IN
ERROR AND 4 FRAME SYNC ERRORS DURING
THIS TIME INTERVAL.

B-6

WS ERRORS DURING I-II STAGING

191335

--------------------SUMMARY--------------------

TAPE NUMBER 10225 — STARTING TIME 30065.1330

TIME INTERVAL 2 — STOPING TIME 30069.1330

OP 6995 "COMB/SEL"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 855. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 13339 — STARTING TIME 30065.1330

TIME INTERVAL 2 — STOPING TIME 30069.1330

OP 6995 "NORMAL"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 784. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 14390 STARTING TIME 30065.1330

TIME INTERVAL 2 STOPING TIME 30069.1330

OP 6995 "SELECT"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 404. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 10215 STARTING TIME 30131.0000

TIME INTERVAL 3 STOPING TIME 30146.0000

OP 6995 "COMB"

THERE WERE 500 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 112 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 216. WORDS IN ERROR AND 10 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

B-10

WS ERRORS DURING THIRD STAGE BURN

191323

-----SUMMARY-----

TAPE NUMBER 13339 STARTING TIME 30131.0000

TIME INTERVAL 3 STOPING TIME 30146.0000

OP 6995 "NORMAL"

THERE WERE 500 RECORDS SCANED IN THIS
TIME INTERVAL OF WHICH 198 CONTAINED
WORD SYNC ERRORS.
THERE WERE A TOTAL OF 879. WORDS IN
ERROR AND 15 FRAME SYNC ERRORS DURING
THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

1913/5

-----SUMMARY-----

TAPE NUMBER 10225 STARTING TIME 30131.0000

TIME INTERVAL 3 **OP 6995 "COMB/SEL"** STOPING TIME 30146.0000

THERE WERE 500 RECORDS SCANED IN THIS
TIME INTERVAL OF WHICH 146 CONTAINED
WORD SYNC ERRORS.

THERE WERE A TOTAL OF 451. WORDS IN
ERROR AND 9 FRAME SYNC ERRORS DURING
THIS TIME INTERVAL.

B-12

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 143[illegible]

TIME INTERVAL 3

STARTING TIME 30131.0000

STOPING TIME 30145.0000

OP 6995 "SELECT"

THERE WERE 467 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 283 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 2872. WORDS IN ERROR AND 50 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 15026 STARTING TIME 39247.6790

TIME INTERVAL 1 STOPING TIME 39250.6790

OP 1160 "COMB"

THERE WERE 100 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 9 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 366. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 14651 | STARTING TIME 39247.6790

TIME INTERVAL 1 | STOPING TIME 39250.6790

OP 1160 "COMB/SEL"

THERE WERE 100 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 11 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1667. WORDS IN ERROR AND 8 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

OP 1160 "SELECT"

TAPE NUMBER 14677 | STARTING TIME 39247.6790

TIME INTERVAL 1 | STOPING TIME 39250.6790

THERE WERE 100 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 14 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 660. WORDS IN ERROR AND 9 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

SUMMARY

TAPE NUMBER 558

TIME INTERVAL 1

OP 1160 "NORMAL"

STARTING TIME 39247.6790

STOPING TIME 39250.6790

THERE WERE 100 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH S CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 662. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 15026

TIME INTERVAL 2

STARTING TIME 39308.2360

STOPING TIME 39312.2360

DP 1160 "COMB"

THEPE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 5 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1002. WORDS IN ERROR AND 5 FRAME SYNC ERRORS DURING THIS TIME INTEPVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 14651

TIME INTERVAL 2

STARTING TIME 39308.2360

STOPING TIME 39312.2360

OP 1160 "COMB/SEL"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1024. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

OP 1160 "SELECT"

TAPE NUMBER 14677 | STARTING TIME 39308.2360

TIME INTERVAL 2 | STOPING TIME 39312.2360

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 5 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1356. WORDS IN ERROR AND 5 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

SUMMARY

TAPE NUMBER [illegible]

TIME INTERVAL [illegible]

STARTING TIME 39308.2360

STOPING TIME 39312.2360

OP 1160 "NORMAL"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 5 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 559. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

B-21

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 15026 | STARTING TIME 39374.0000

TIME INTERVAL 3 | OP 1160 "COMB" | STOPING TIME 39383.0000

THERE WERE 300 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 27 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 272. WORDS IN ERROR AND 5 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 14651

TIME INTERVAL 3

STARTING TIME 39374.0000

STOPING TIME 39383.0000

DP 1160 "COMB/SEL"

THERE WERE 300 RECORDS SCANED IN THIS
TIME INTERVAL OF WHICH 28 CONTAINED
WORD SYNC ERRORS.

THERE WERE A TOTAL OF 195. WORDS IN
ERROR AND 4 FRAME SYNC ERRORS DURING
THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

OP 1160 "SELECT"

TAPE NUMBER 14677 STARTING TIME 39374.0000

TIME INTERVAL 3 STOPING TIME 39383.0000

THERE WERE 300 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 36 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 686. WORDS IN ERROR AND 9 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

SUMMARY

TAPE NUMBER [illegible]

TIME INTERVAL [illegible]

OP 1160 "NORMAL"

STARTING TIME 39374.0000

STOPING TIME 39389.0000

THERE WERE 5[illegible] RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 101 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 366. WORDS IN ERROR AND 3 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

B-25

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 13173

TIME INTERVAL 1

STARTING TIME 48299.6610

STOPING TIME 48304.0790

OP 5649 "SELECT"

THERE WERE 148 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 13 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 474. WORDS IN ERROR AND 8 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 13276

TIME INTERVAL 1

OP 5649 "COMB/SEL"

STARTING TIME 48299.6610

STOPING TIME 48304.0790

THERE WERE 148 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 6 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 298. WORDS IN ERROR AND 5 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER [illegible]

TIME INTERVAL 1

OP 5649 "NORMAL"

STARTING TIME 48299.6610

STOPING TIME 48304.0790

THERE WERE 148 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 307. WORDS IN ERROR AND 2 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 13173

TIME INTERVAL 2

OP 5649 "SELECT"

STARTING TIME 48361.0000

STOPING TIME 48365.0360

THERE WERE 135 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1043. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-11 STAGING

SUMMARY

TAPE NUMBER 13276

TIME INTERVAL 2

OP 5649 "COMB/SEL"

STARTING TIME 48361.0000

STOPING TIME 48365.0360

THERE WERE 135 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 898. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 13463

TIME INTERVAL 2

OP 5649 "NORMAL"

STARTING TIME 48361.0000

STOPING TIME 48365.0360

THERE WERE 135 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 894. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

B-31

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 13173

TIME INTERVAL 3

OP 5649 "SELECT"

STARTING TIME 48425.4000

STOPING TIME 48440.0000

THERE WERE 486 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 127 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1711. WORDS IN ERROR AND 30 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 13278

STARTING TIME 48425.4000

TIME INTERVAL 3

OP 5649 "COMB/SEL"

STOPING TIME 48440.0000

THERE WERE 486 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 121 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1343. WORDS IN ERROR AND 26 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 13463 — STARTING TIME 48425.4000

TIME INTERVAL 3 — **OP 5649 "NORMAL"** — STOPING TIME 48440.0000

THERE WERE 486 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 195 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 2058. WORDS IN ERROR AND 37 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 11801

TIME INTERVAL 1

OP 87 41 "NORMAL"

STARTING TIME 23399.7480

STOPING TIME 23403.7480

THERE WERE 132 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 2 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 23. WORDS IN ERROR AND 1 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 11737

TIME INTERVAL 1

STARTING TIME 23399.7480

STOPING TIME 23403.7480

DP 8741 "COMB"

THERE WERE 132 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 6 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 223. WORDS IN ERROR AND 1 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 11[illegible]

TIME INTERVAL 1

OP 8741 "COMB/SEL"

STARTING TIME 23399.7480

STOPING TIME 23403.7480

THERE WERE 132 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 5 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 19. WORDS IN ERROR AND 0 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER 11671 | STARTING TIME 23399.7480

TIME INTERVAL 1 | STOPING TIME 23403.7480

OP 8741 "SELECT"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 16 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 2349. WORDS IN ERROR AND 11 FRAME SYNC ERRORS DURING THIS TIME INTEPVAL.

WS ERRORS DURING LIFT-OFF

SUMMARY

TAPE NUMBER [illegible] — STARTING TIME 23459.5270

TIME INTERVAL [illegible] — STOPING TIME 23463.5270

OP 8741 "NORMAL"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 440. WORDS IN ERROR AND 3 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 11747 | STARTING TIME 23459.5270

TIME INTERVAL 2 | STOPING TIME 23463.5270

DP 8741 "COMB"

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1070. WORDS IN ERROR AND 4 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE NUMBER 11560

TIME INTERVAL 2

OP 8741 "COMB/SEL"

STARTING TIME 23459.5270

STOPING TIME 23463.5270

THERE WERE 133 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 4 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 436. WORDS IN ERROR AND 3 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING I-II STAGING

SUMMARY

TAPE [illegible]   STARTING TIME 23522.7390

TIME INTERVAL 1   STOPING TIME 23537.5390

OP 8741 "COMB"

THERE WERE 492 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 142 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 1029. WORDS IN ERROR AND 14 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER [illegible]

TIME INTERVAL 2

OP 8741 "COMB"

STARTING TIME 23568.3900

STOPING TIME 23583.2900

THERE WERE 498 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 40 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 141. WORDS IN ERROR AND 5 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 13414

TIME INTERVAL 1

OP 8741 "COMB/SEL"

STARTING TIME 23522.7390

STOPING TIME 23537.5390

THERE WERE 492 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 44 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 152. WORDS IN ERROR AND 2 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 1341.

TIME INTERVAL 2

OP 8741 "COMB/SEL"

STARTING TIME 23568.3900

STOPING TIME 23583.2900

THERE WERE 498 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 35 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 145. WORDS IN ERROR AND 5 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 10426

TIME INTERVAL 1

STARTING TIME 23522.7390

STOPING TIME 23537.5390

OP 8741 "NORMAL"

THERE WERE 460 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 141 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 388. WORDS IN ERROR AND 10 FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 10426 STARTING TIME 23568.3900

TIME INTERVAL 2 STOPING TIME 23583.2900

OP 8741 "NORMAL"

~~THERE WERE 498 RECORDS SCANED IN THIS~~

TIME INTERVAL OF WHICH 47 CONTAINED

WORD SYNC ERRORS.

THERE WERE A TOTAL OF 102. WORDS IN

ERROR AND 3 FRAME SYNC ERRORS DURING

THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 13471 — STARTING TIME 23522.7390

TIME INTERVAL 1 — STOPING TIME 23[illegible]37.5390

OP 8741 "SELECT"

THERE WERE 460 RECORDS SCANED IN THIS TIME INTERVAL OF WHICH 45 CONTAINED WORD SYNC ERRORS.

THERE WERE A TOTAL OF 120. WORDS IN ERROR AND C FRAME SYNC ERRORS DURING THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

SUMMARY

TAPE NUMBER 13471 | STARTING TIME 23563.3900

TIME INTERVAL 2 | STOPING TIME 23583.2900

OP 8741 "SELECT"

THERE WERE 498 RECORDS SCANED IN THIS
TIME INTERVAL OF WHICH 57 CONTAINED
WORD SYNC ERRORS.

THERE WERE A TOTAL OF 142. WORDS IN
ERROR AND 3 FRAME SYNC ERRORS DURING
THIS TIME INTERVAL.

WS ERRORS DURING THIRD STAGE BURN

APPENDIX C

DIVERSITY COMBINER AM/AGC CONTROL TECHNIQUE

21 AUGUST 1975

TABLE OF CONTENTS

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LIST OF TABLES

1.0 INTRODUCTION

This preliminary report is published in response to System Performance Analysis Task TM-5020 which directs that test and evaluation of the AM/AGC Receiver - Combiner Interface Unit be performed. This report contains operational verification test results obtained with a multipath simulation test set plus data recorded during missile launch operations.

The Naval Missile Center (NMC), under a task from the Range Commanders Council/ Telemetry Group, designed, fabricated and lab tested a circuitry to implement both the AM detected IF signals and AGC voltages from the telemetry receivers to control the diversity combiner. The circuitry was packaged in a special interface unit which is easily wired through patch panel connectors between the receivers and the combiner. A detailed description of the unit including theory of operation, circuit schematics, and operating procedures was provided with the unit. The NMC description is contained in Appendix A in its entirety.

The primary advantage of the interface unit is the ability of the AM detector to follow rapid RF signal fades which the relatively slow receiver AGC circuitry does not respond to. The interface unit can then properly weigh the control voltages which the combiner uses to sum the two receiver data signals. Operational verification tests demonstrated that the interface unit does produce faster receiver channel selection during alternate channel fading. Alternate channel fading is the condition where Right Circular Polarization (RCP) signals fade or Left Circular Polarization (LCP) signals fade but one of the two is always present. This condition occurs during missile manuevering, missile spin for stabilization and powered flight where the signal must penetrate the flame.

Launch data showed that the combiner controlled by the interface unit was able to retrieve some of the data not obtained by an AGC controlled combiner during the rapid fade conditions of third stage burn of the Minuteman III missile. The test combiner and normal AGC controlled combiner were equivalent during the remainder of the flight.

After testing of the interface unit began, a Diversity Signal Characterization Unit (DSCU) was also received. This unit contains phase detectors, amplitude detectors and comparators that measure the phase difference between the RCP and LCP receiver IF signals and the amplitude of the individual channels. The detector outputs frequency modulate 450 KHz carriers for recording on tape. This information contains the exact requirements that the combiner must meet. The DSCU is scheduled for use at each of the test ranges to determine actual multipath conditions. The data has been sent to the Pacific Missile Test Center (PMTC) for evaluation. No analysis is contained in this report.

2.0 OBJECTIVES

The objectives of the testing described in this report are:

a. To demonstrate that the interface unit does improve combiner channel selection under rapid alternate channel fade conditions.

b. To measure any improvement in data recovery over that of a standard AGC controlled combiner during the multipath conditions of a missile launch operation.

c. To determine the limiting factors in using the AM/AGC combiner control technique.

3.0 TESTS AND TEST RESULTS

3.1 Operational Verification Tests

3.1.1 AM Detector Response

The equipment was operated as shown in Figure 1. The function generator controlling the combiner test set was set for a 100 Hz square wave output to cause very sharp, well defined fades. A 100 Hz fade rate was selected to prevent any ambiguity in measuring the attack and release response times. Attack time is defined as the time between the 10% and 90% levels of the voltage change due to a 20 db increase in RF signal power. Release time is defined as the time between the 90% and 10% levels of the voltage change due to a 20 db decrease in RF signal power.

Both the receiver AGC input to the interface unit and the "AGC Output" of the interface unit were displayed on a dual trace oscilloscope for comparison. The AGC attack time was approximately 0.2 ms when 0.1 ms time constant was selected. Release time was the same. These AGC results are nominal (see Reference 2). The AM detector attack and release times were both approximately 0.03 ms at selections of 0.1 ms, 1.0 ms, 10.0 ms, 100.0 ms or 1000.0 ms AGC time constant. This result was expected since the AM detector output is filtered by a 30 KHz Low Pass Filter.

3.1.2 Dynamic Alternate Channel Fade Test

With the equipment configured as shown in Figure 1 for the previous test, the control voltages of the function generator were sine waves set at 180° out of phase to cause alternate channel fading but one channel would always be present. A detailed description of the combiner test set theory of operation is contained in Reference 3. The signal generator level was set to establish a BER of $1X10^{-6}$ on a single channel. The combiner output produced no errors to confirm that the combiner provided a SNR improvement under steady state conditions, i.e., no fading. With fading turned on, the combiner maintained a BER of $1X10^{-6}$ until the fade frequency or control frequency exceeded 400 Hz. The BER count increased to $100X10^{-6}$ at 401 Hz then deteriorated to totally unmeasurable data at 430 Hz. 400 Hz is

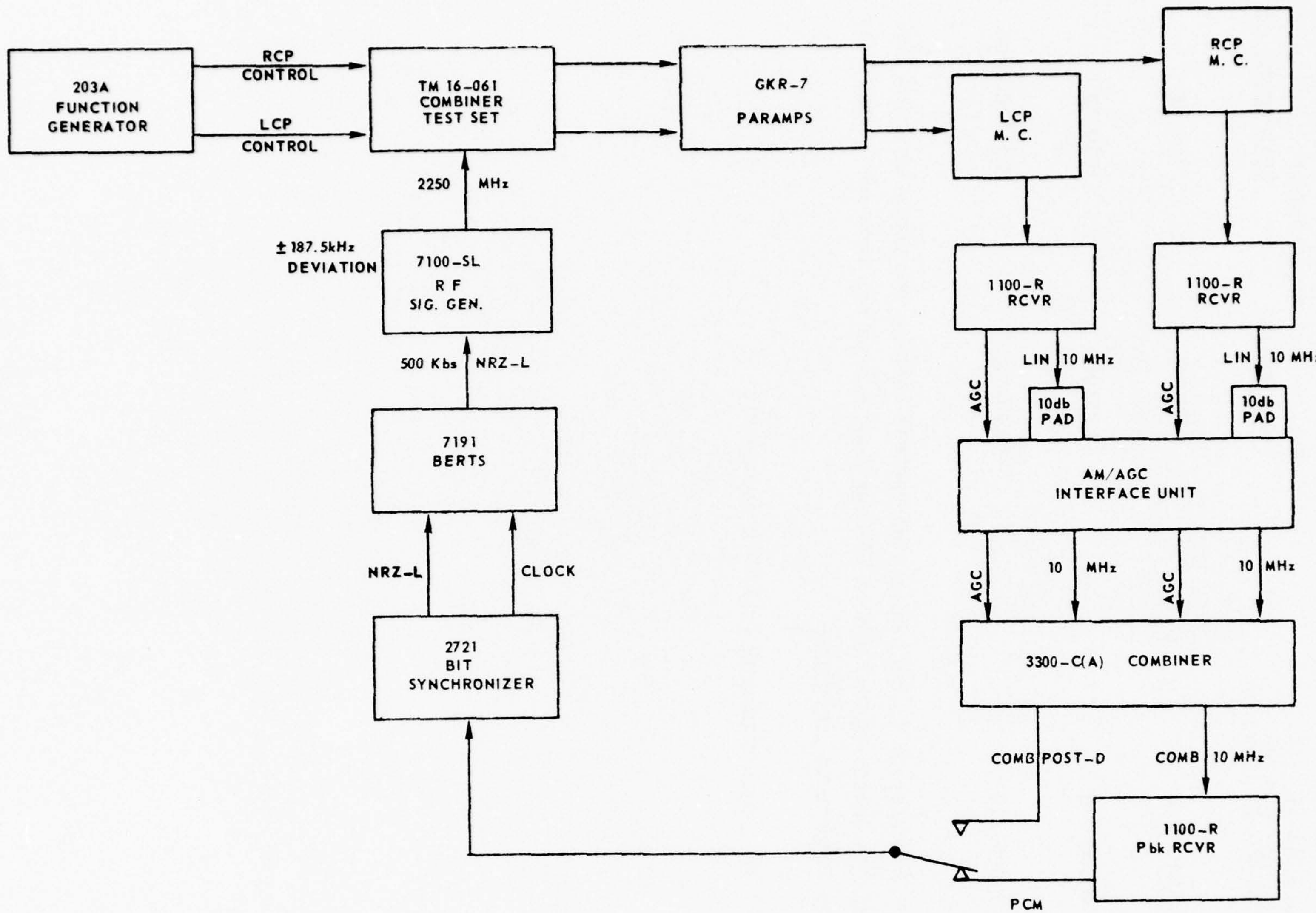


FIGURE 1 OPERATIONAL VERIFICATION TEST CONFIGURATION

Table 1. Alternate Channel Fading Test Results

Combiner Test Set Control Voltage	Break Point* Predetection	Break Point* Post-detection
Figure 2.a	400 Hz	190 Hz
Figure 2.b	4000 Hz	1170 Hz
Figure 2.c	**4300 Hz	Not Recorded

* Break point is defined as the control voltage frequency at which the BER increases by two orders of magnitude due to the combiner's inability to respond to the fades.

** Test result provided by PMTC personnel.

designated as the break frequency. The AM/AGC interface unit appeared to provide exactly the same results as a normally controlled AGC combiner. A review of the test data forwarded with the unit showed that the NMC combiner test set control voltages were not the same as those used at the SAMTEC. The NMC combiner interface unit tests had shown a 4000 Hz break point or the expected order of magnitude increase in selection speed as indicated by the difference between the 0.2 ms AGC response time and the 0.03 ms AM plus AGC response time.

The combiner test set control voltages as shown in Figure 2.a were then set as shown in Figure 2.b to rerun the tests. The test results listed in Table 1 then confirmed the NMC test results. Note that post-detection combining is always worse than predetection combining. These results are consistent with the results of Reference 3. The degradation of the post-detection data is believed to be caused by saturation of the receiver video amplifier during noisy signal conditions. In addition, the change in signal level when switching from one channel to the other must be accommodated by the bit synchronizer for post-detection data but is compensated by the high frequency circuitry of the combiner for predetection data.

At this point in the test program, G. Law and D. Hatfield of the PMTC delivered the DSCU. D. Hatfield gave a briefing on the DSCU and D. Law provided test results and answered questions on the AM/AGC interface unit. The NMC (now PMTC) combiner test set control voltages are illustrated in Figure 2.c. The reason for the difference in test results on the break frequency can be seen by comparison to Figure 2.a. The times between RF signal fades are significantly different. The IRIG Document 118-75, Test Methods for Telemetry Systems and Subsystems, will soon establish testing compatibility when released this year. The above two personnel also provided valuable assistance in prelaunch verification testing of the two units. In particular, they discovered that the linear 10 MHz levels from the two Microdyne Model 1100-R receivers were 6 db apart. A 6 db attenuator was added to one channel to complete the tests. These levels are not adjustable. Recommendations are made in Section 6.0. This problem has not impacted launch support since the limited 10 MHz signals are used at all SAMTEC sites and are routinely adjusted.

FIGURE 2a. SAMTEC COMBINER TEST SET CONTROL VOLTAGES

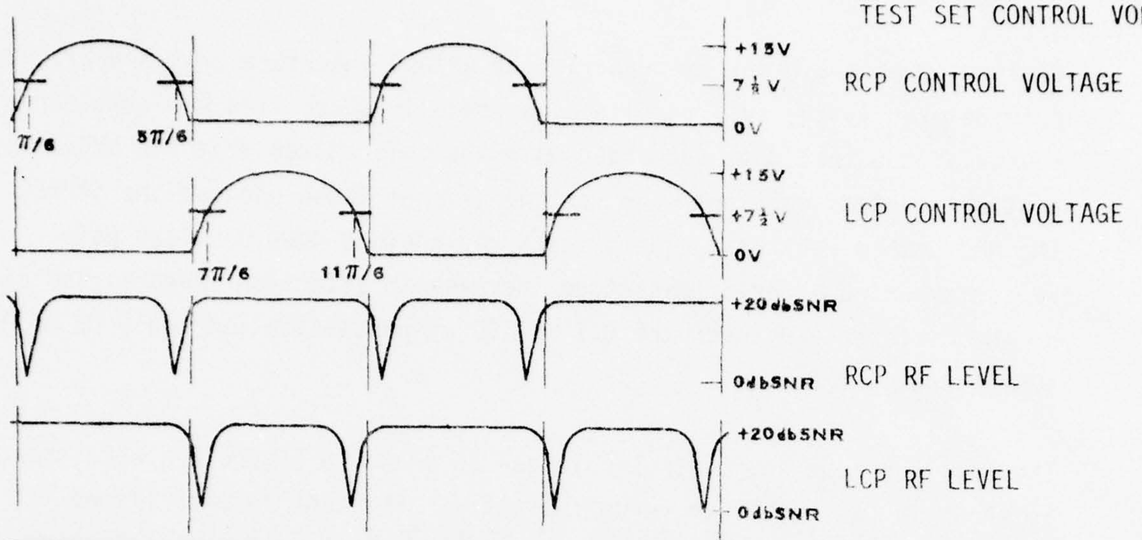


FIGURE 2b. ADJUSTED CONTROL VOLTAGES

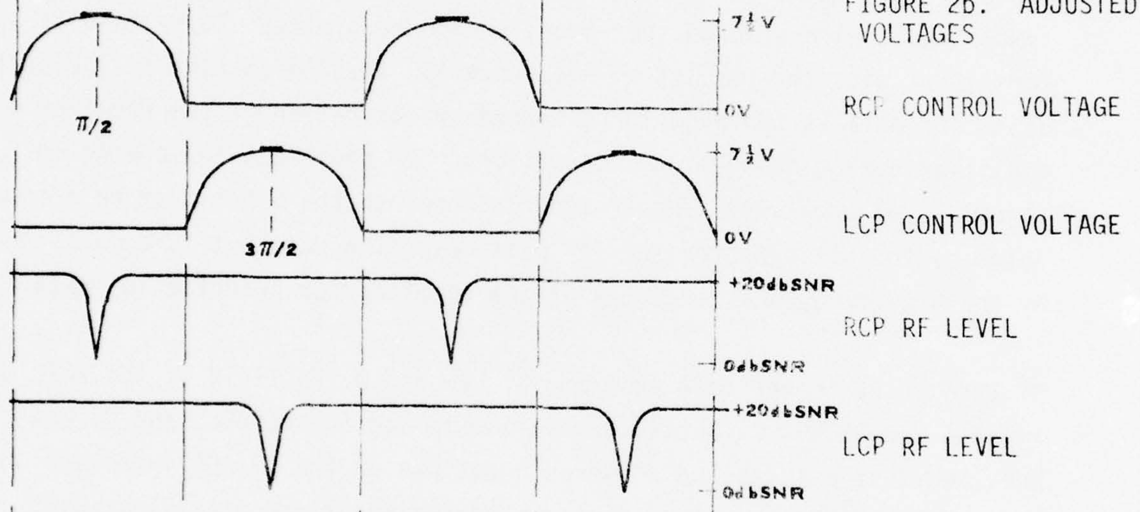
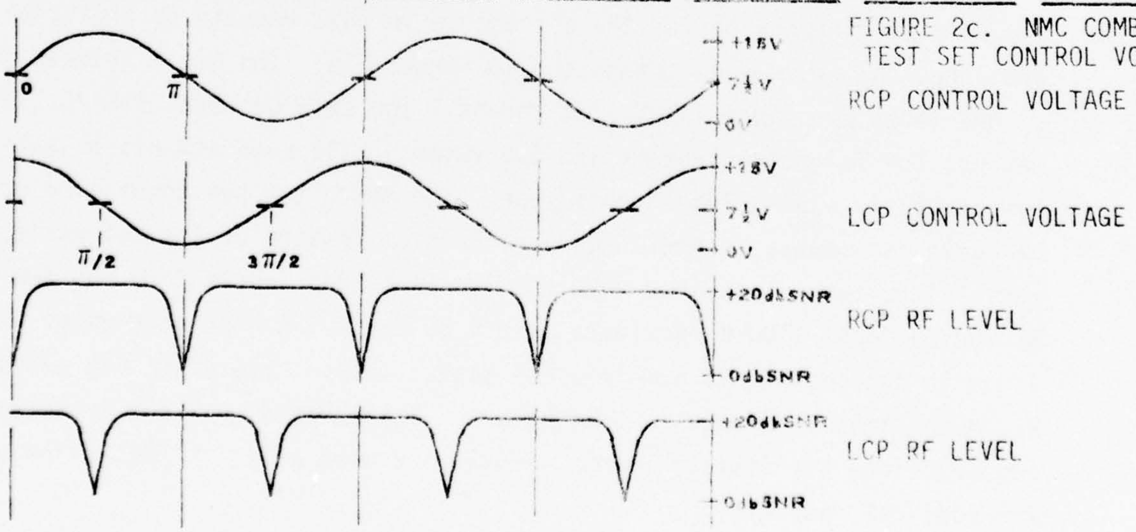


FIGURE 2c. NMC COMBINER TEST SET CONTROL VOLTAGES



3.2 Launch Data

Four launch operations were supported but useful data was obtained from only two. A Titan III D launch was supported on 7 June as part of Operation 6381. The 6 db difference in level between the two receiver linear 10 MHz outputs caused the AM/AGC controlled combiner to produce worse data than an AGC controlled combiner. Since the trajectory produces aspect angles greater than 15° and the liquid fuel causes less degradation than solid fuel, data degradation was only caused for a few seconds near lift-off and at staging where a comparison of the combiners could be made. Error free data was provided during most of the flight. Minuteman Launch Operation 4227 on 11 June provided no data due to failure of the backup antenna azimuth drive system shortly before the launch. However, two Minuteman III launch operations were successfully supported for test purposes. The data from these two operations confirmed the results of the operational verification tests.

Support of Minuteman missile launches was preferred over any other type of launch vehicle to obtain the worst case multipath conditions. From the SAMTEC viewpoint, the heavy multipath interference at lift-off, staging and especially during the flame noise during third stage burn is the problem area where the combiner could improve data recovery. Practically no data loss occurs at the uprange and mid-range tracking sites for any other part of the flight. Reentry is not supported by SAMTEC sites and is not addressed in this report.

3.2.1 Launch Operation 7173

This Minuteman III launch operation on 20 June provided recorded magnetic tape data of predetection combined signals from both AGC controlled and AM/AGC controlled combiners. Data degradation occurred only at lift-off, staging, shroud ejection, and during third stage burn. Both combiners provided error free data even during spin-up since the alternate channel fades were at a rate of less than 50 Hz. Flame noise during third stage burn lasts approximately a minute and provides the best opportunity to compare the two types of combiner control. The DSCU was utilized during

this operation to produce a second magnetic tape of the signals measuring phase difference between the RCP and LCP channels plus individual amplitude measurements of each channel. Dubs of both tapes were sent to PMTC for evaluation.

Playbacks of the DSCU amplitude measurements showed the fade rates during third stage burn to average between 1 KHz and 10 KHz with some periods at higher rates. This data agrees with that of Reference 4. The phase difference between the RCP and LCP channels indicated a constant 160 Hz frequency difference throughout the flight. The independent operation of the receiver second L.O.'s was determined to be the cause. The first L.O.'s are always phaselocked or else a common source drives both receivers. Each receiver second L.O. has its own crystal reference but one can be phaselocked to the other. The second L.O.'s are normally operated in the crystal mode. Both modes were tested in the succeeding launch operation.

The Minuteman data format is PCM, Bi-ϕ-L/PM. The PCM frame synchronization (FS) pattern is 27 bits long at a repetition rate of 30 ms. The word synchronization (WS) pattern is 3 bits long at a repetition rate of 78 μs. A display of FS status on a strip chart showed that during third stage burn an indicator with better than a 30 ms response time was required to measure the differences in performance between the combiners. Hundreds of data words could be lost between FS indicators. Computer scans of every WS pattern were made to determine the time and number of patterns in errors. WS errors are plotted in Figures 3 through 10. The total number of WS errors during the time frame of each figure is also annotated in the legend for each combiner.

Figure 3 shows that the AM/AGC controlled combiner produced significantly fewer errors near liftoff than the AGC controlled combiner. Both combiners were nearly equivalent near staging since recovery is not a matter of selection but of signal availability on either channel. Note the fact that the signal-to-noise ratio (SNR) is high, greater than 30 db, before and after the fades as indicated by signal strength records. Figures 4, 5, and 6 indicate that the AM/AGC controlled combiner produces worse data than the AGC controlled combiner. The average SNR drops to about 12 db at the

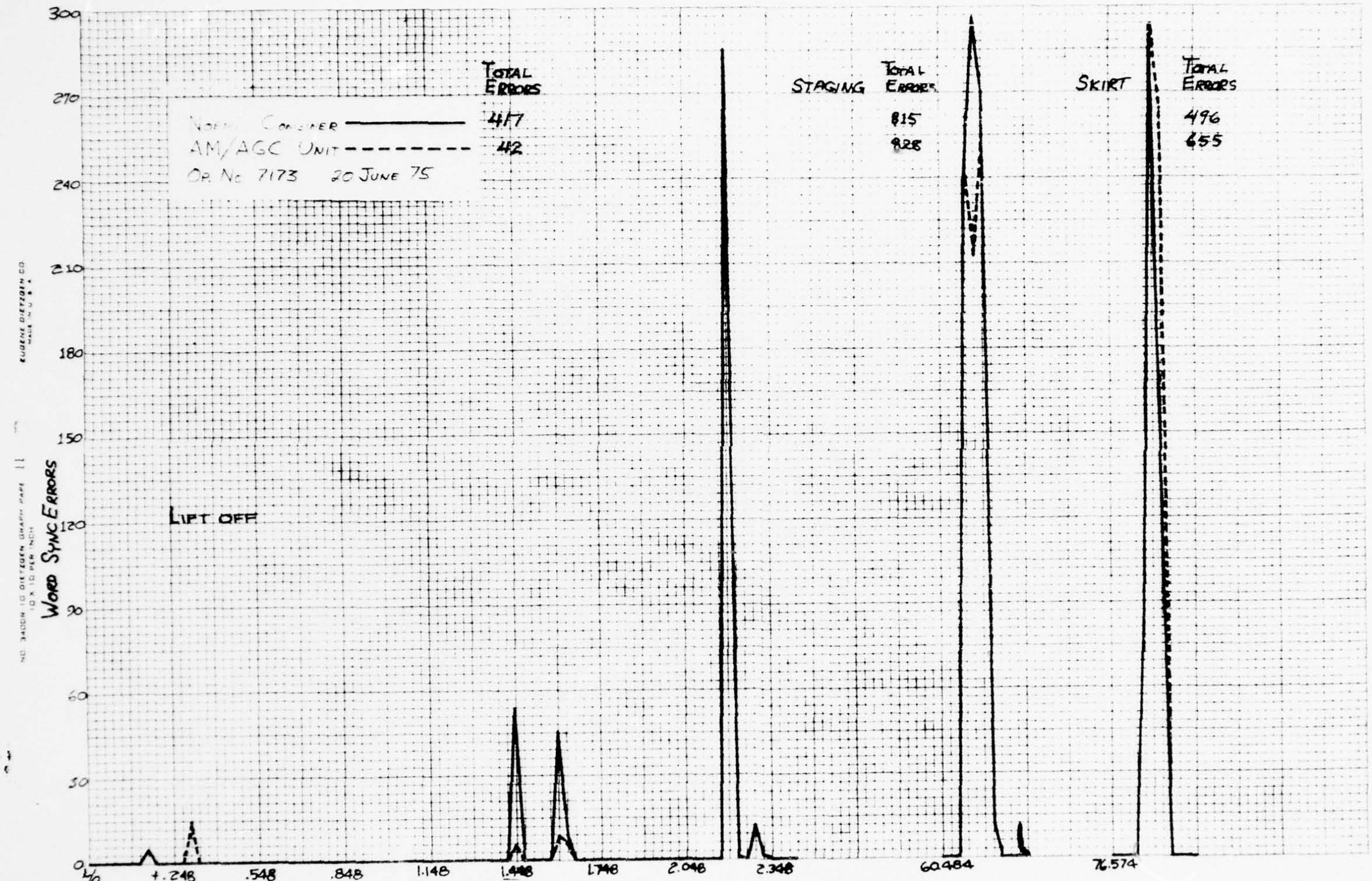


Figure 3 WS Errors Near Liftoff, Staging, and Skirt Ejection

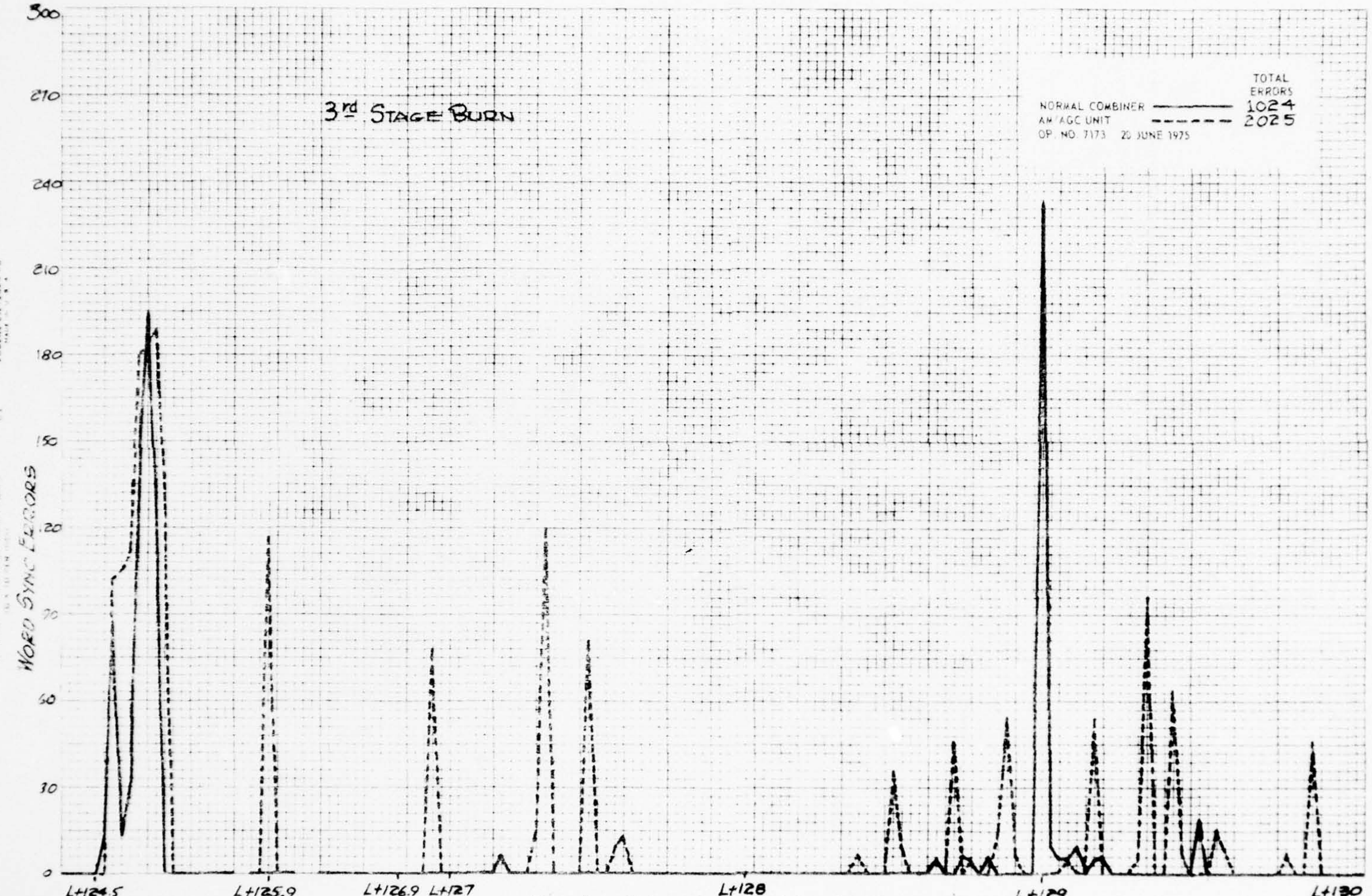


Figure 4 WS Errors During Third Stage Burn (Sheet 1 of 7)

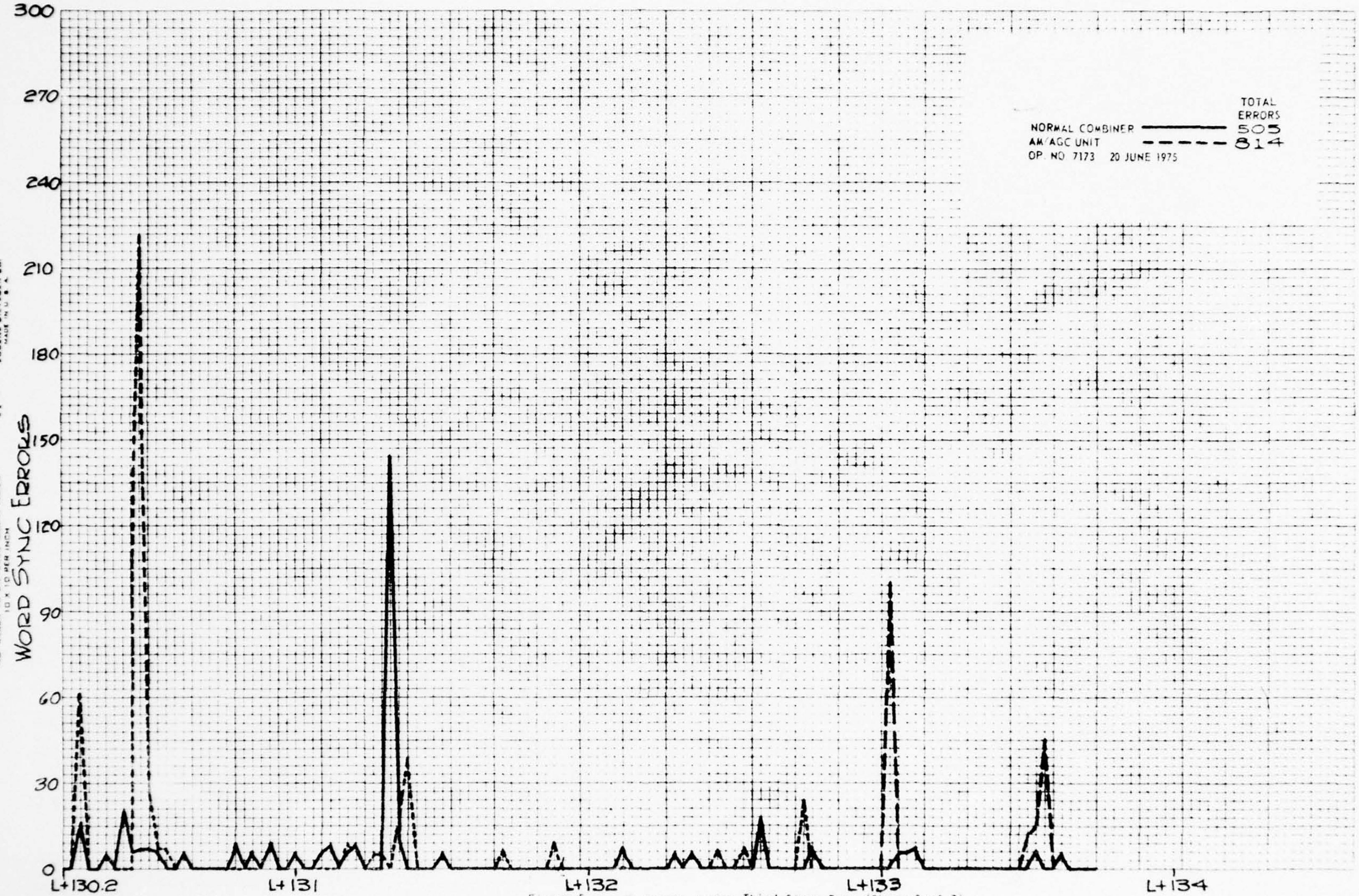


Figure 5 ...s Errors During Third Stage Burn (Sheet 2 of 7)

NO. 340OR-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

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MADE IN U. S. A.

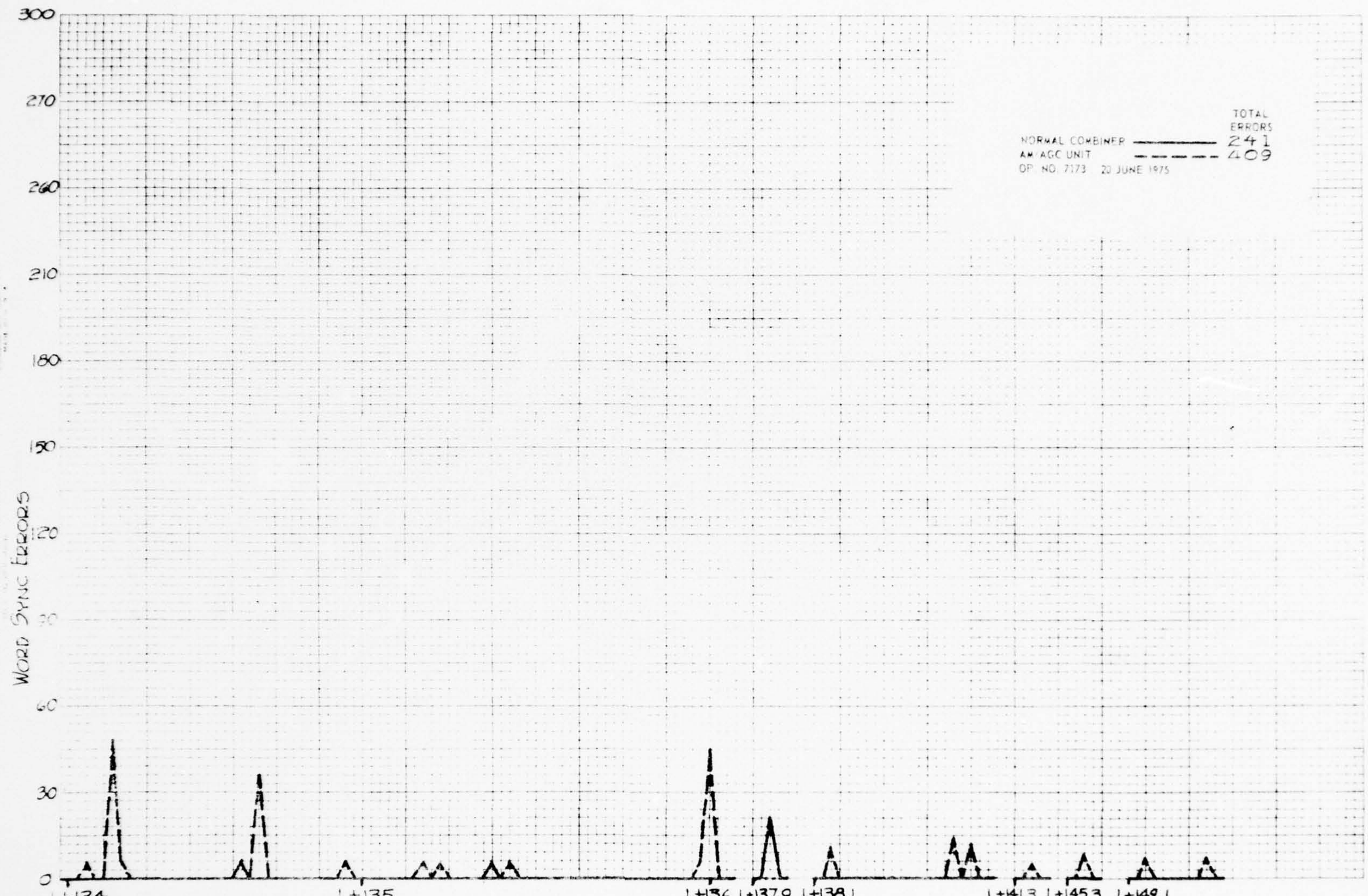

Figure 6 WS Errors During Third Stage Burn (Sheet 3 of 7)

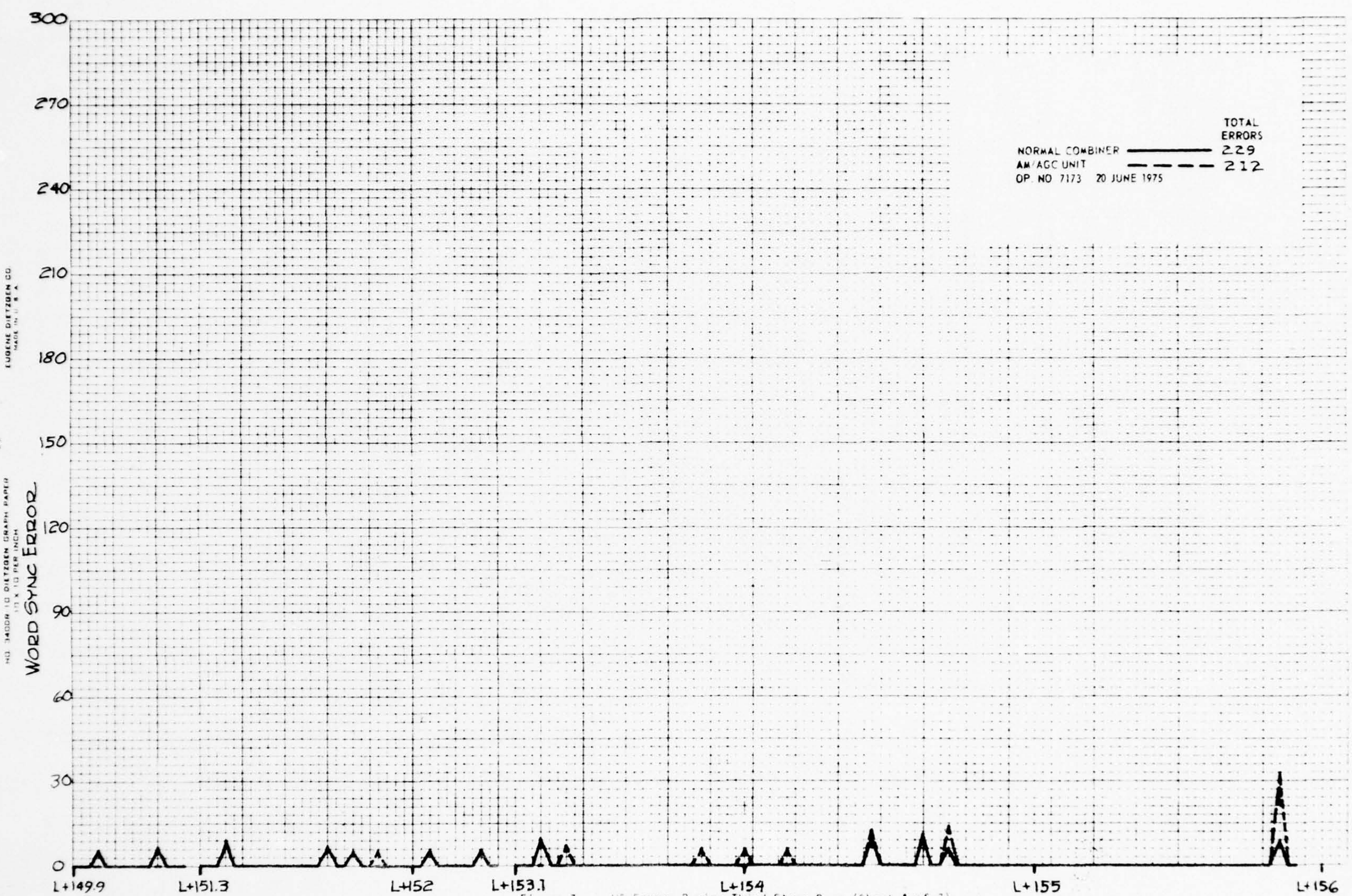

Figure 7 WS Errors During Third Stage Burn (Sheet 4 of 7)

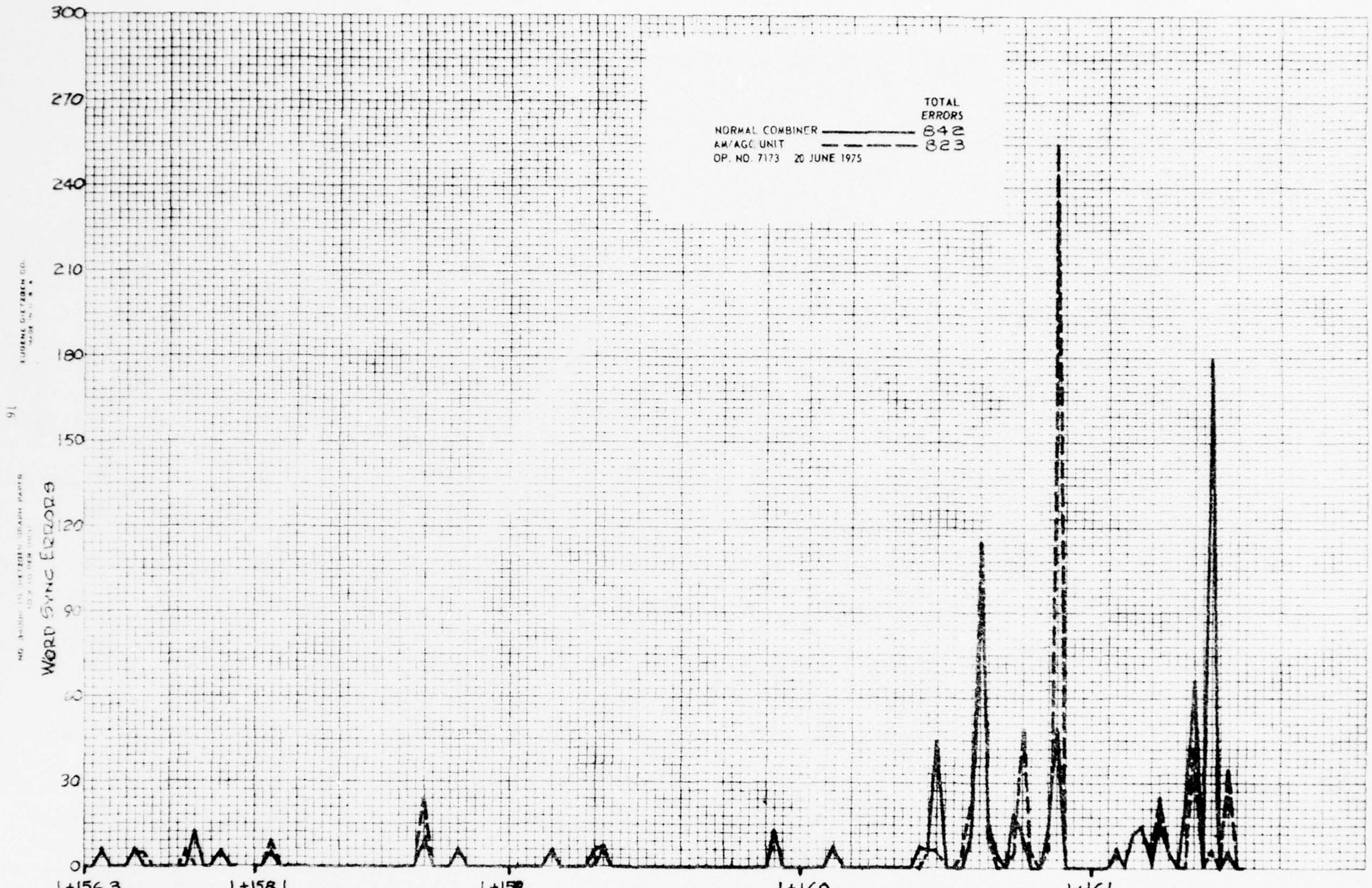

Figure 8 WS Errors During Third Stage Burn (Sheet 5 of 7)

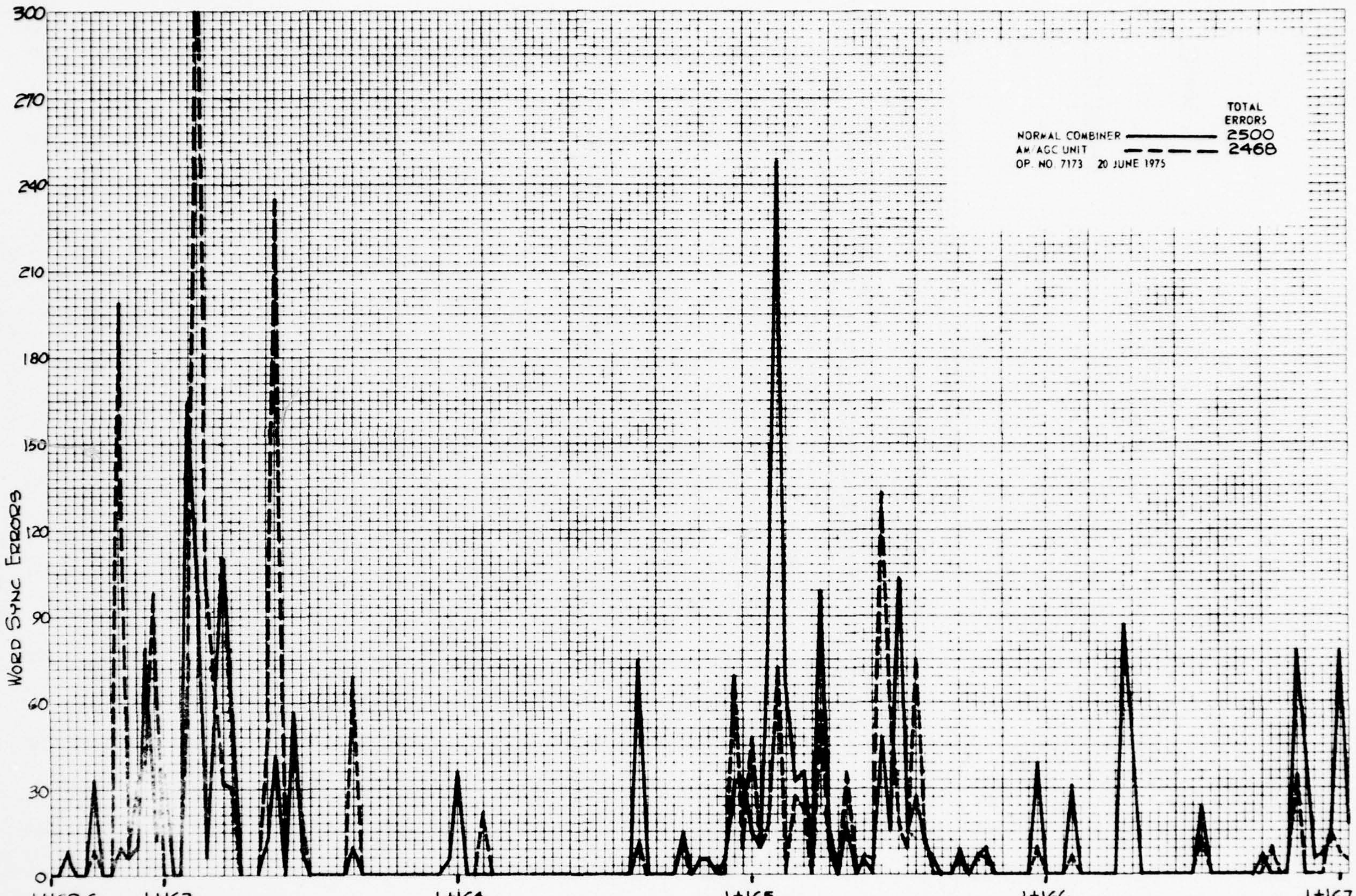

Figure 9 WS Errors During Third Stage Burn (Sheet 6 of 7)

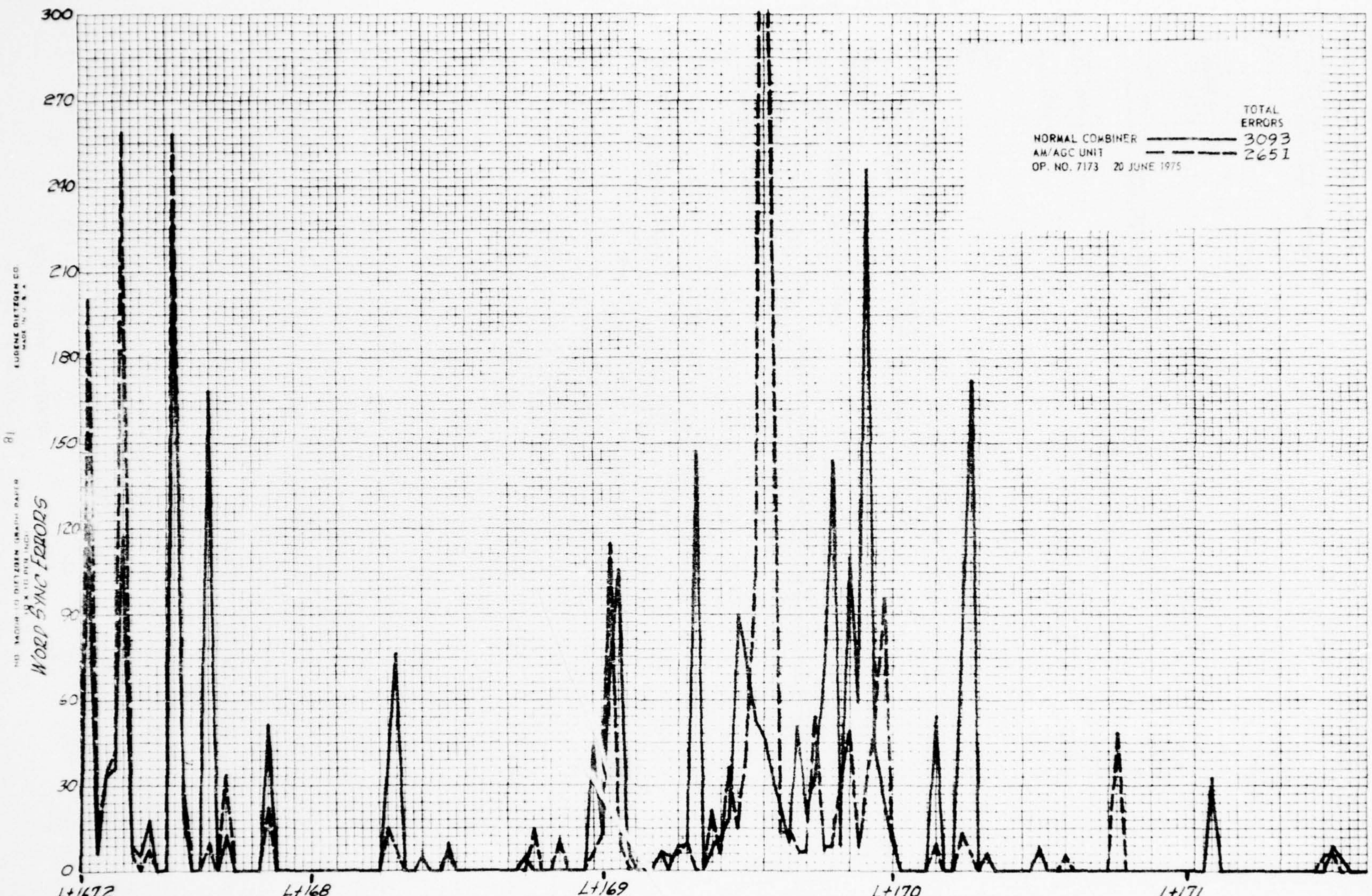

Figure 10 WS Error During Third Stage Burn (Sheet 7 of 7)

beginning of third stage burn and slowly increases as the aspect angle increases. Figures 7 through 10 show the performance of the AM/AGC controlled combiner improve as the SNR increases until the data recovered exceeds that of the AGC controlled combiner. For SNR's below 16 db, the AM/AGC technique resulted in more data loss than the use of AGC alone. In the range of approximately 16 to 20 db SNR both techniques were essentially equivalent. Above 20 db SNR the AM/AGC technique was superior.

3.2.2 Launch Operation 5453

This Minuteman III launch operation on 1 July was supported in the same manner as Launch Operation 7173 with two changes made. The second L.O.'s of the test receivers were phaselocked. And the receiver AGC levels were set to -0.9 V on system noise rather than at -0.5 V or closer to 0.0 V. AGC controlled combiners were operated both with and without the receiver second L.O.'s phaselocked for comparison. The two AGC controlled combiners performed very nearly the same. The small frequency difference between the second L.O.'s appears to be easily acquired and tracked within the 200 Hz loop bandwidth of the combiner. WS errors for all three support configurations are plotted in Figures 11 through 21.

Figure 11 shows that the AM/AGC controlled combiner has eliminated data loss immediately after lift-off due to its increased speed, while both AGC controlled combiners produced degraded data. Figure 12 indicates that the AM/AGC combiner recovers the fastest of any of the combiners after staging. Figure 13 indicates a slight decrease in performance of the AM/AGC controlled combiner due to low SNR. An explanation for this degradation is contained in Section 4.0. Figures 14 through 21 demonstrate superiority of the AM/AGC control technique over AGC control. The quick response of the AM detector is easily seen in any of the large blocks of errors. Some random errors occur in the data from each of the three combiners. An improvement to the present AM/AGC technique is discussed in Section 4.0.

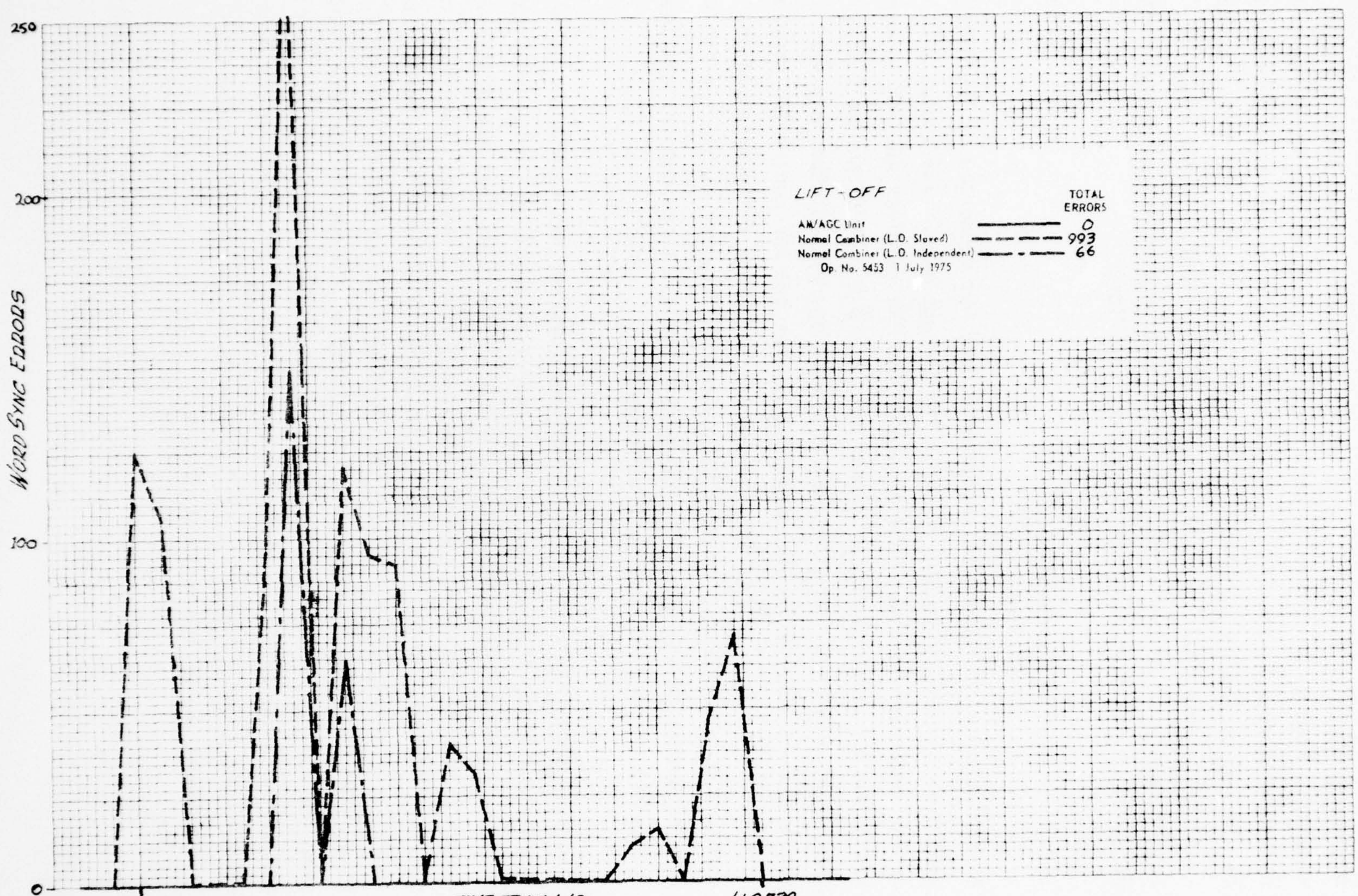

Figure 11 WS Errors Near Liftoff

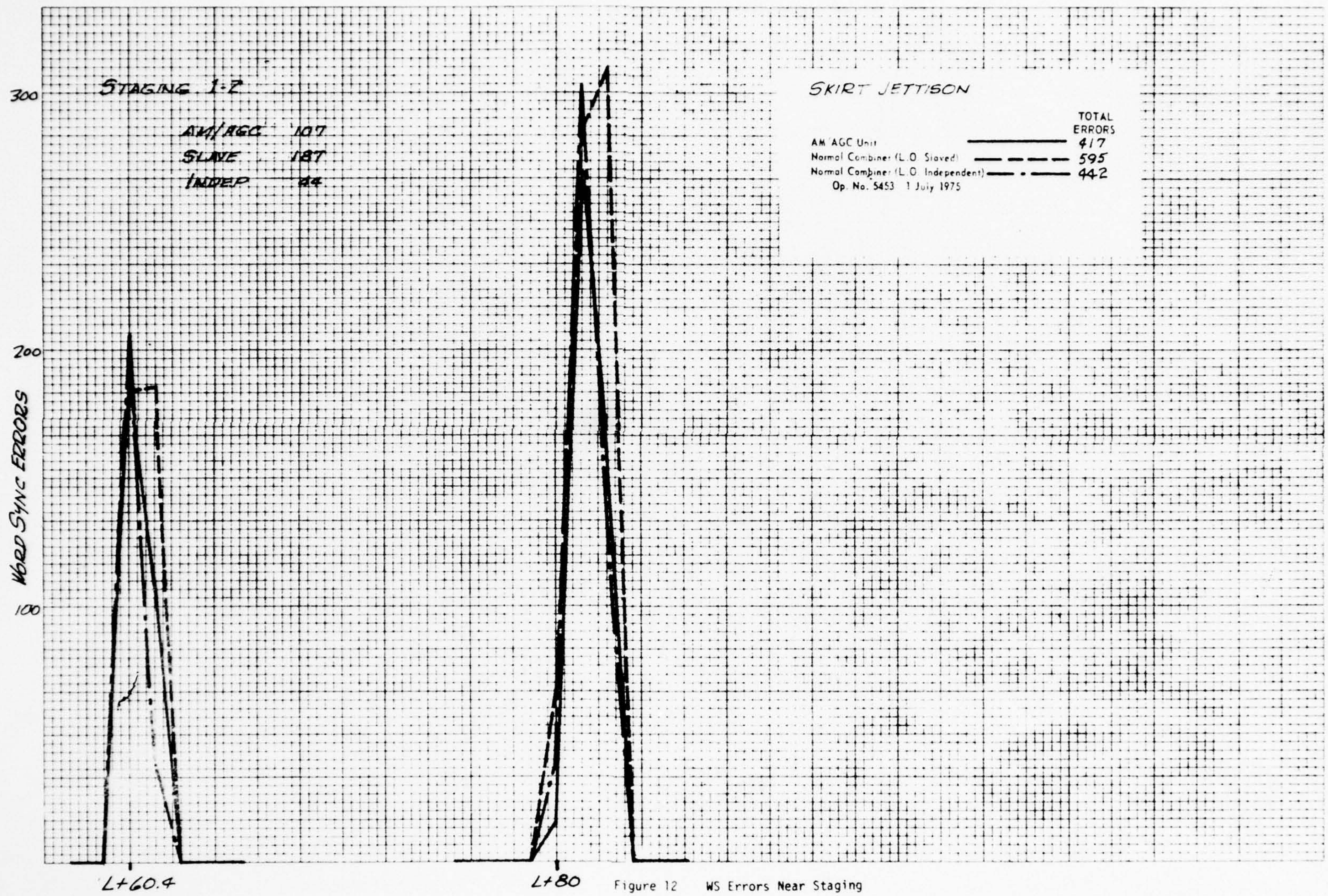

Figure 12 WS Errors Near Staging

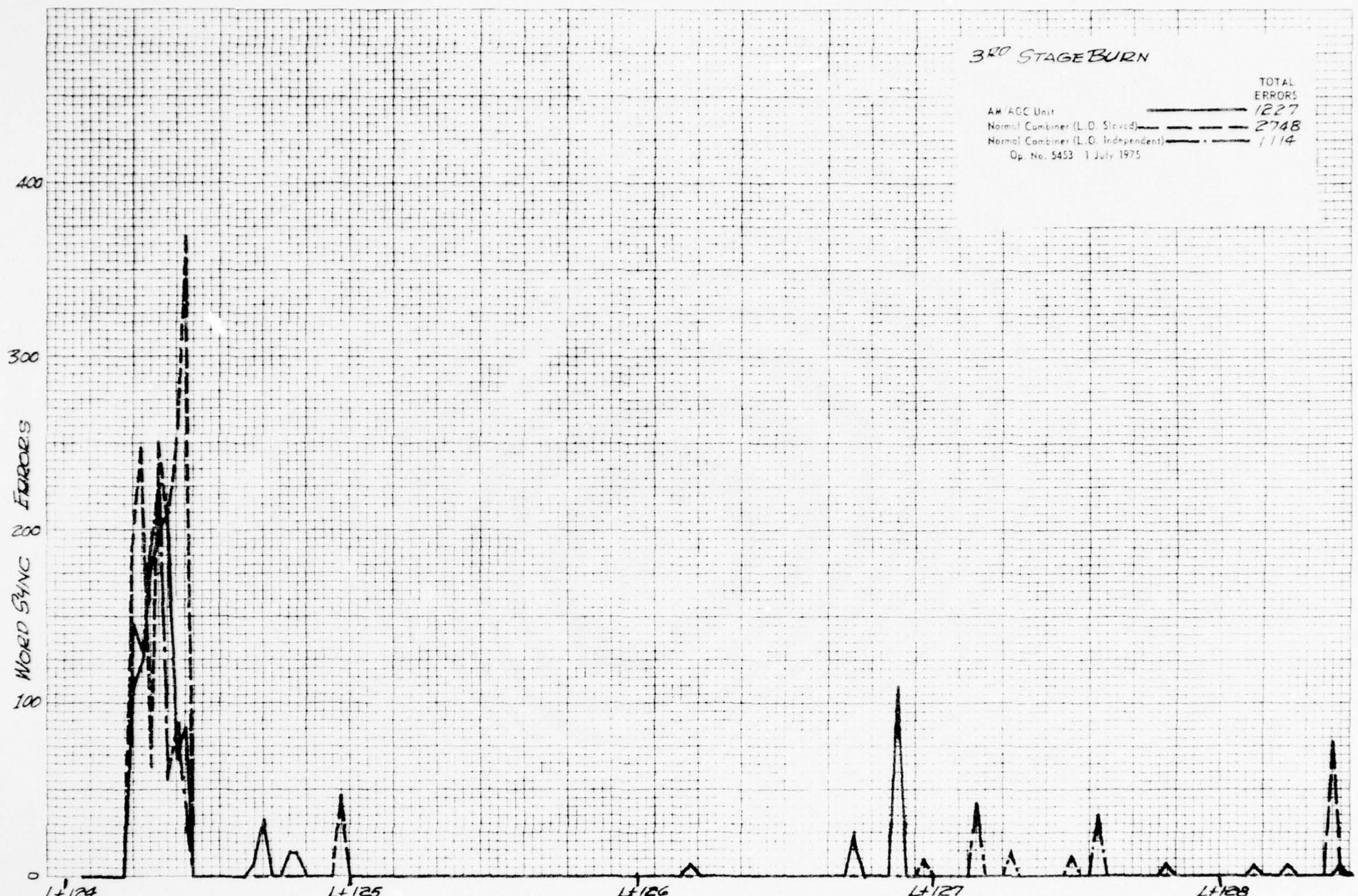

Figure 13 WS Errors During Third Stage Burn (Sheet 1 of 9)

NO. 340DR-10 DIETZGEN GRAPH PAPER 10 X 10 PER INCH
EUGENE DIETZGEN CO. MADE IN U.S.A.

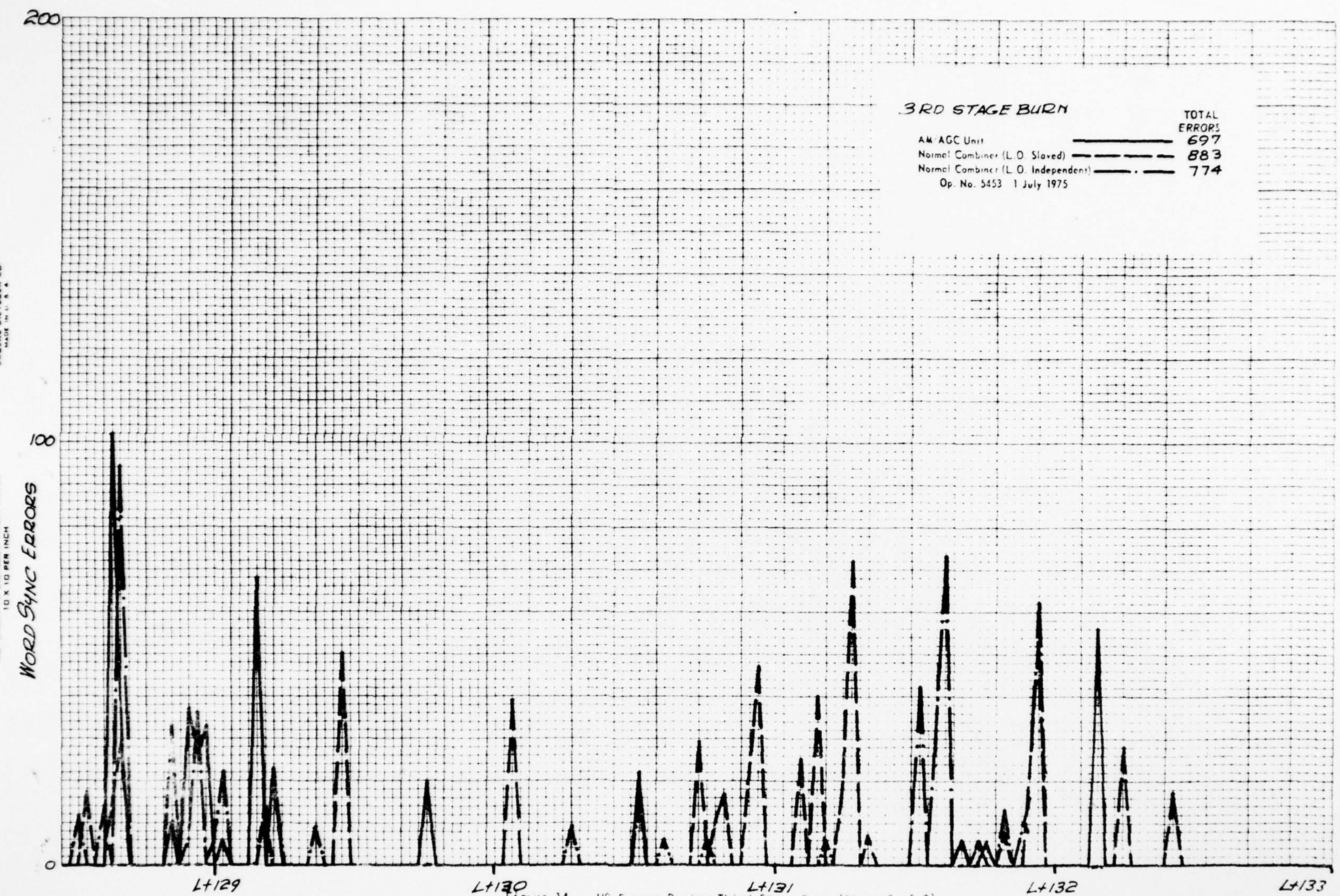

Figure 14 WS Errors During Third Stage Burn (Sheet 2 of 9)

AD-A041 505 FEDERAL ELECTRIC CORP VANDENBERG AFB CALIF F/G 9/6
AM/AGC COMBINER.(U)
FEB 77 V SHIBATA F04701-72-C-0203
UNCLASSIFIED SAMTEC-TR-77-35 NL

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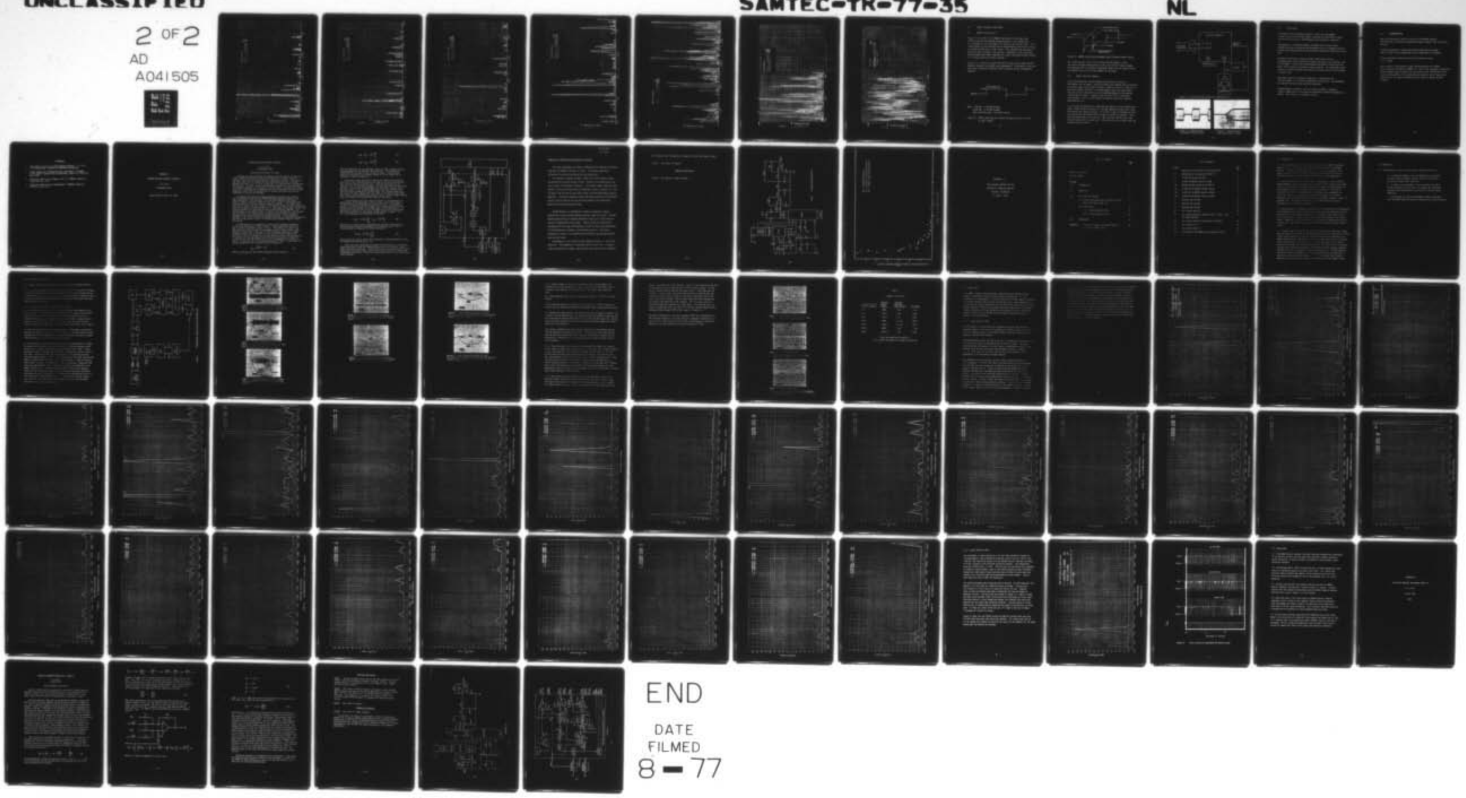

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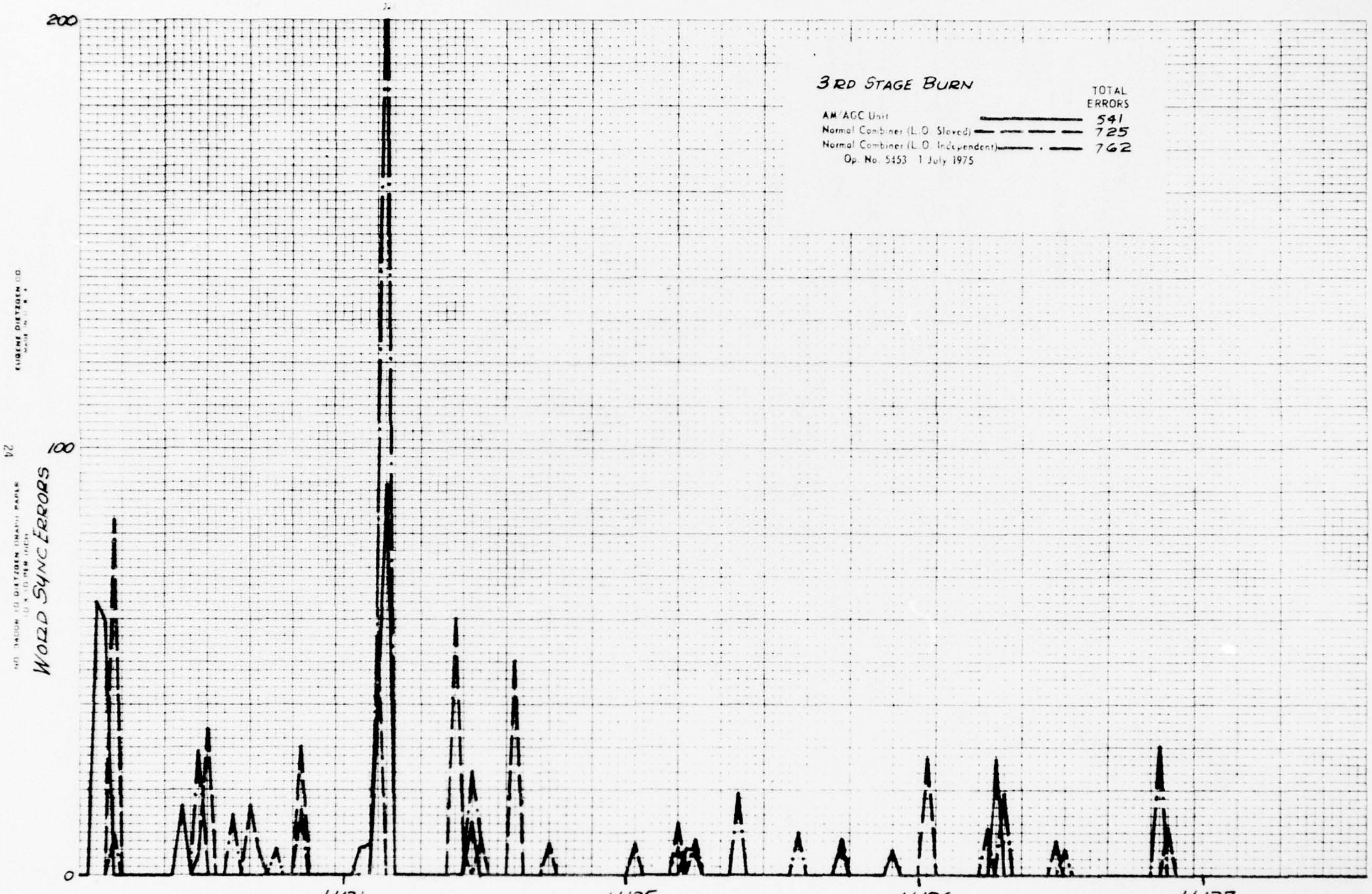


Figure 15 WS Errors During Third Stage Burn (Sheet 3 of 9)

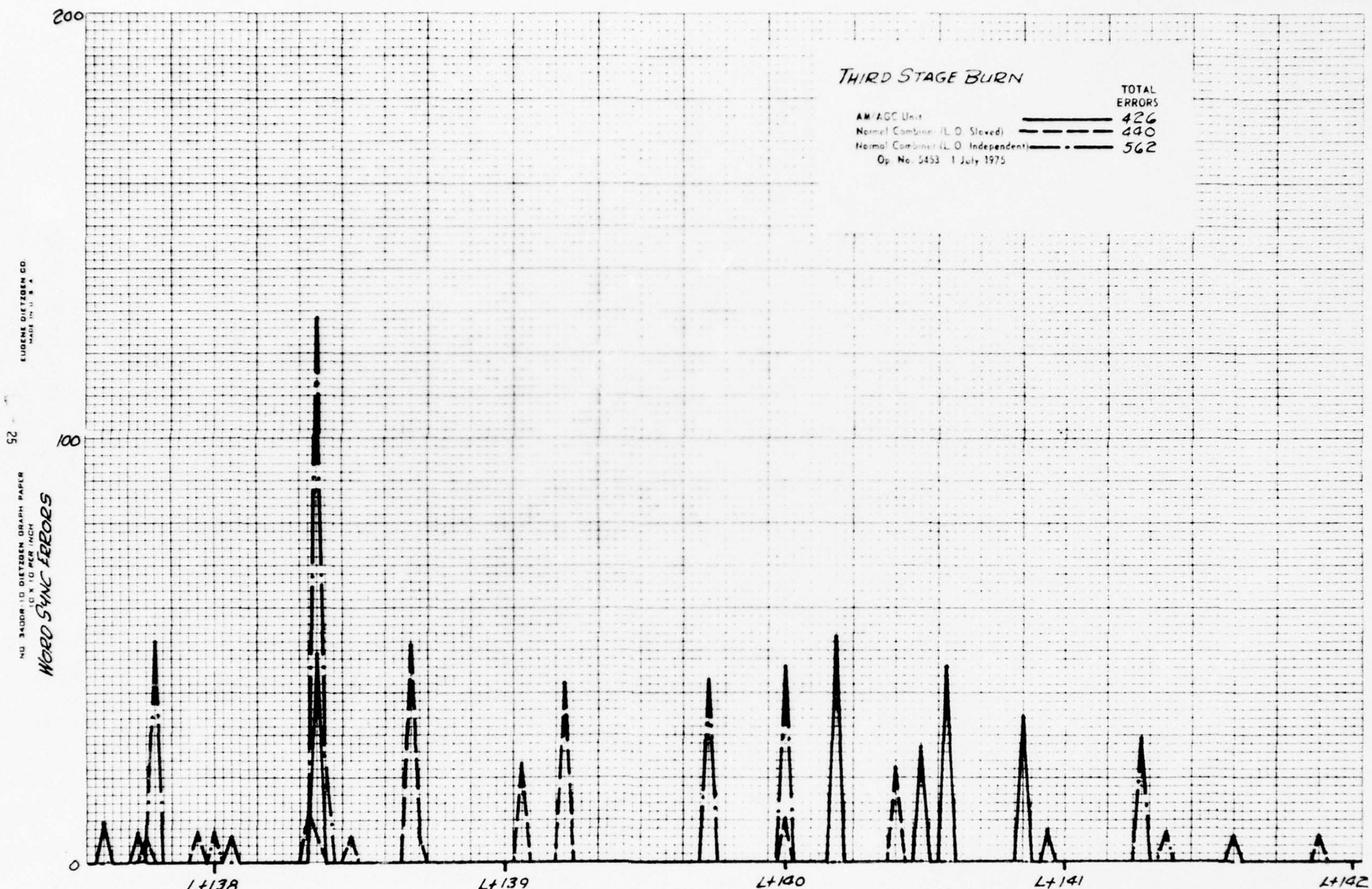


Figure 16 WS Errors During Third Stage Burn (Sheet 4 of 9)

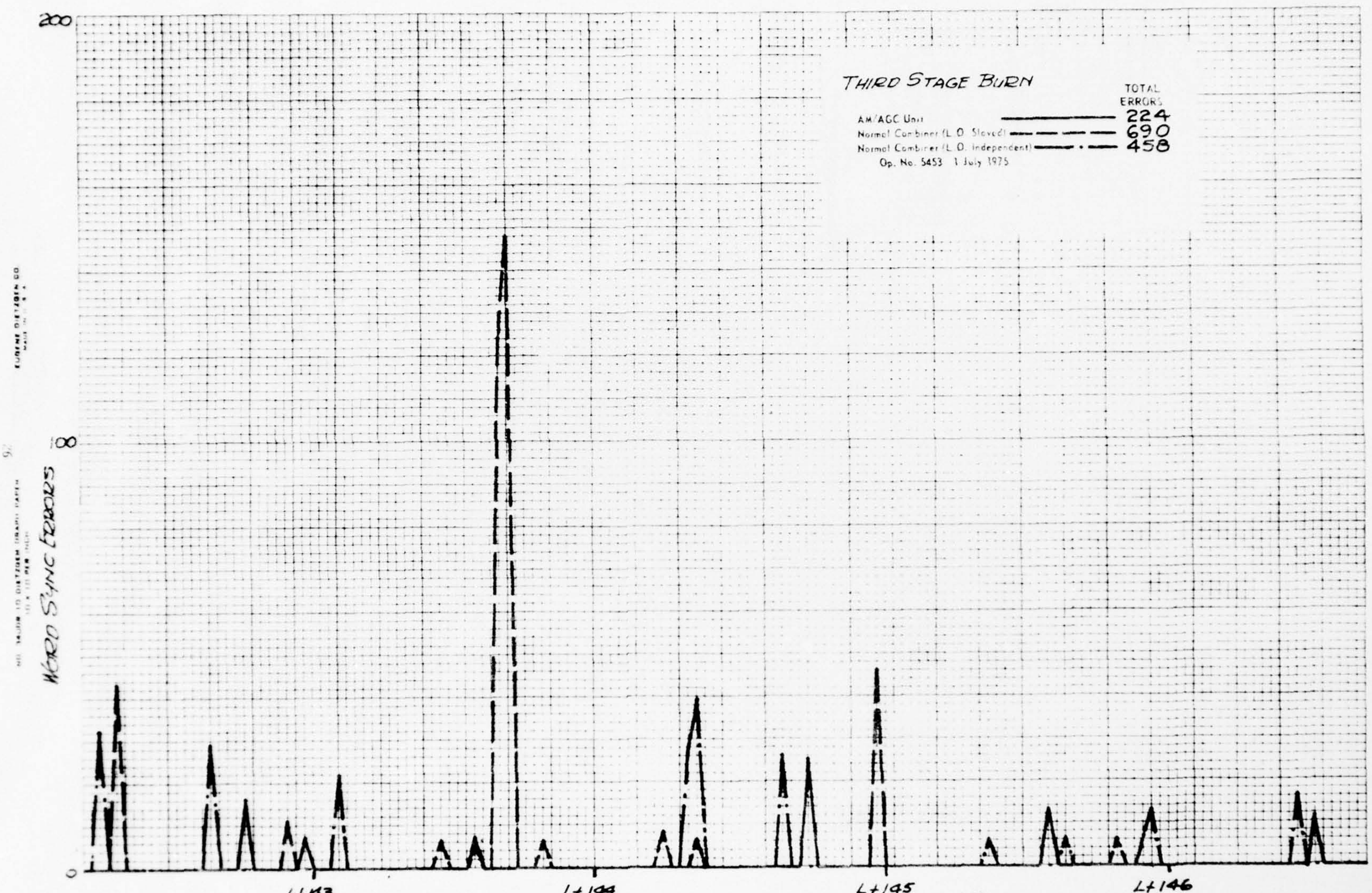


Figure 17 WS Errors During Third Stage Burn (Sheet 5 of 9)

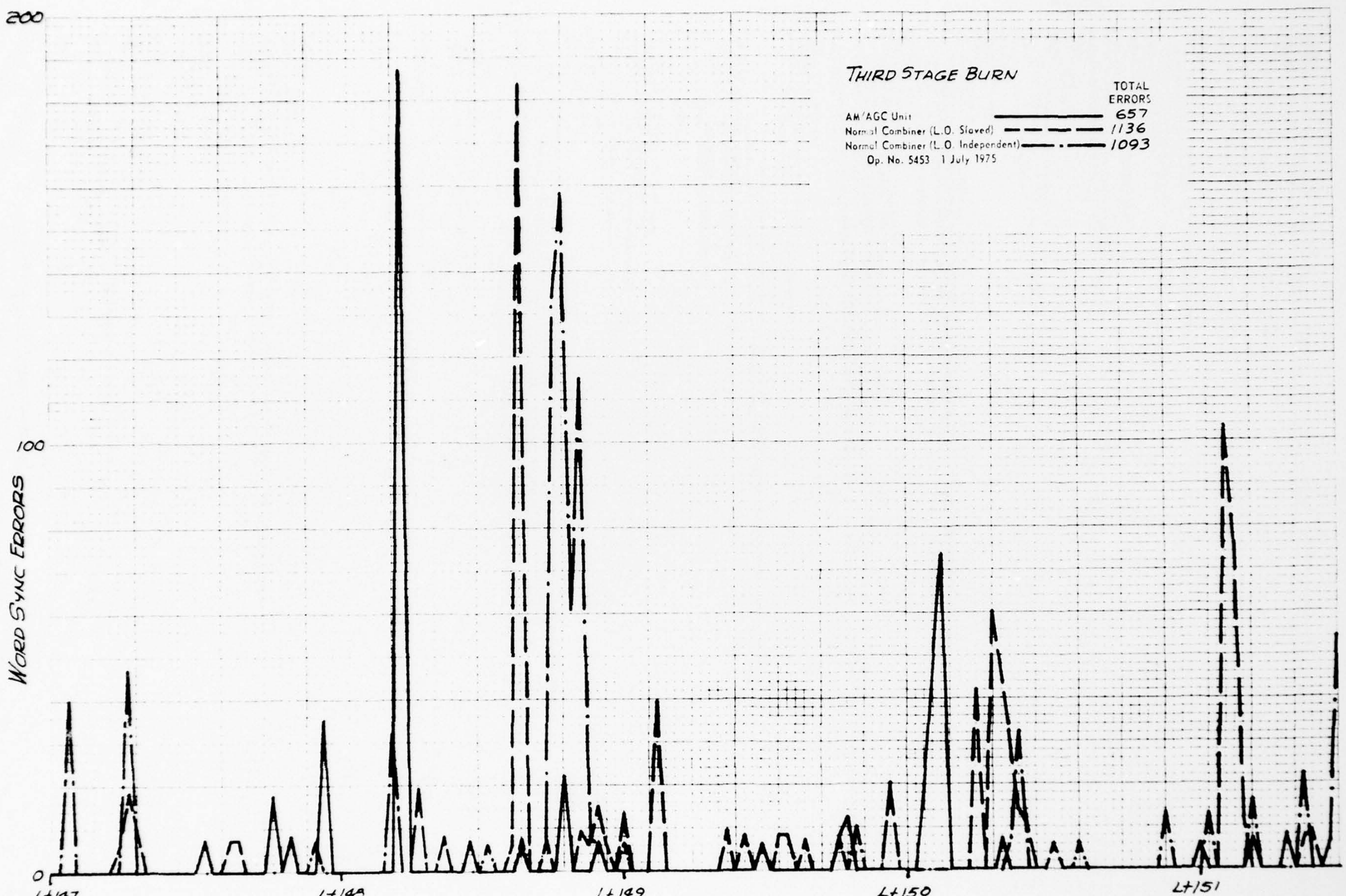


Figure 18 WS Errors During Third Stage Burn (Sheet 6 of 9)

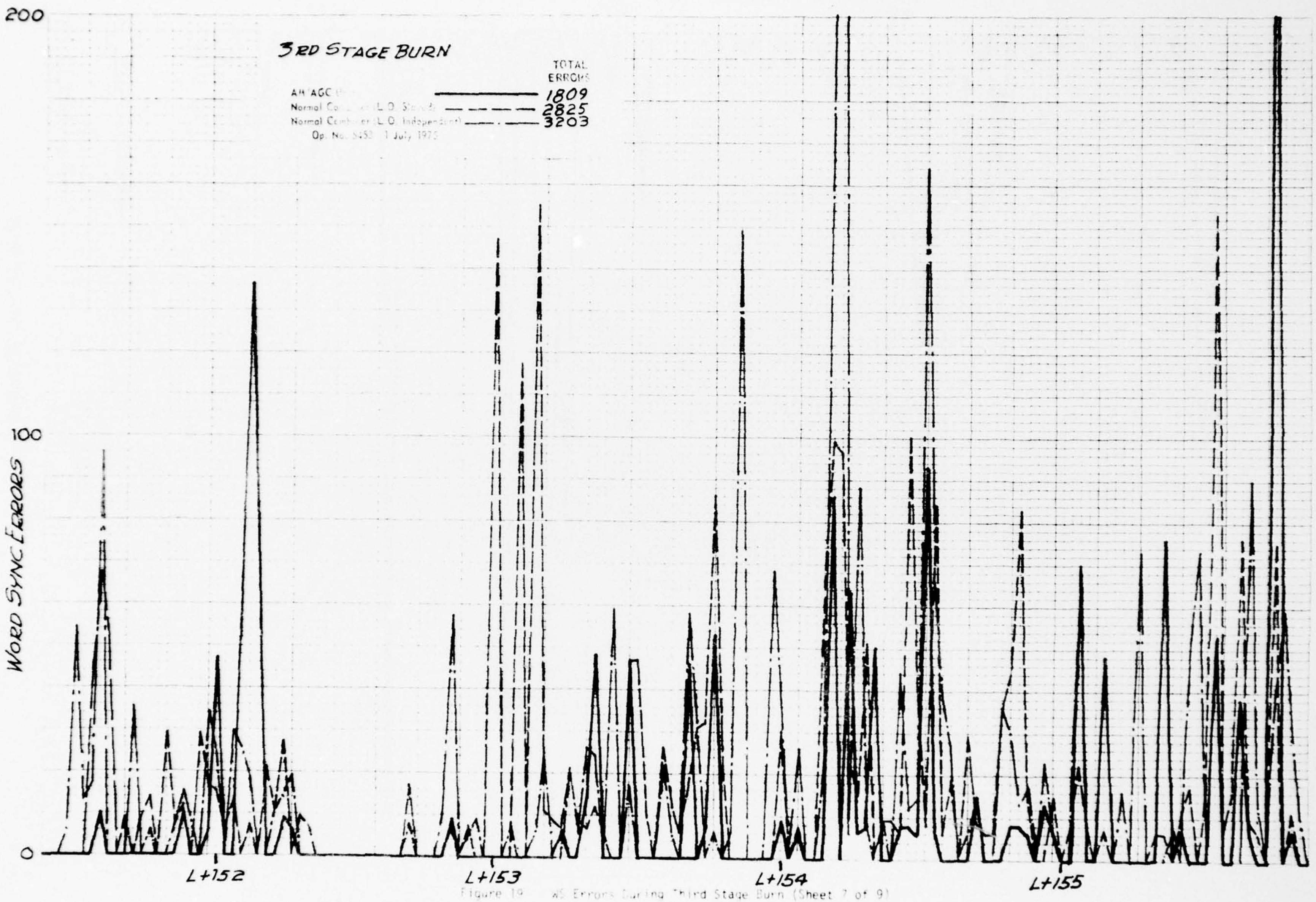


Figure 19 WS Errors During Third Stage Burn (Sheet 7 of 9)

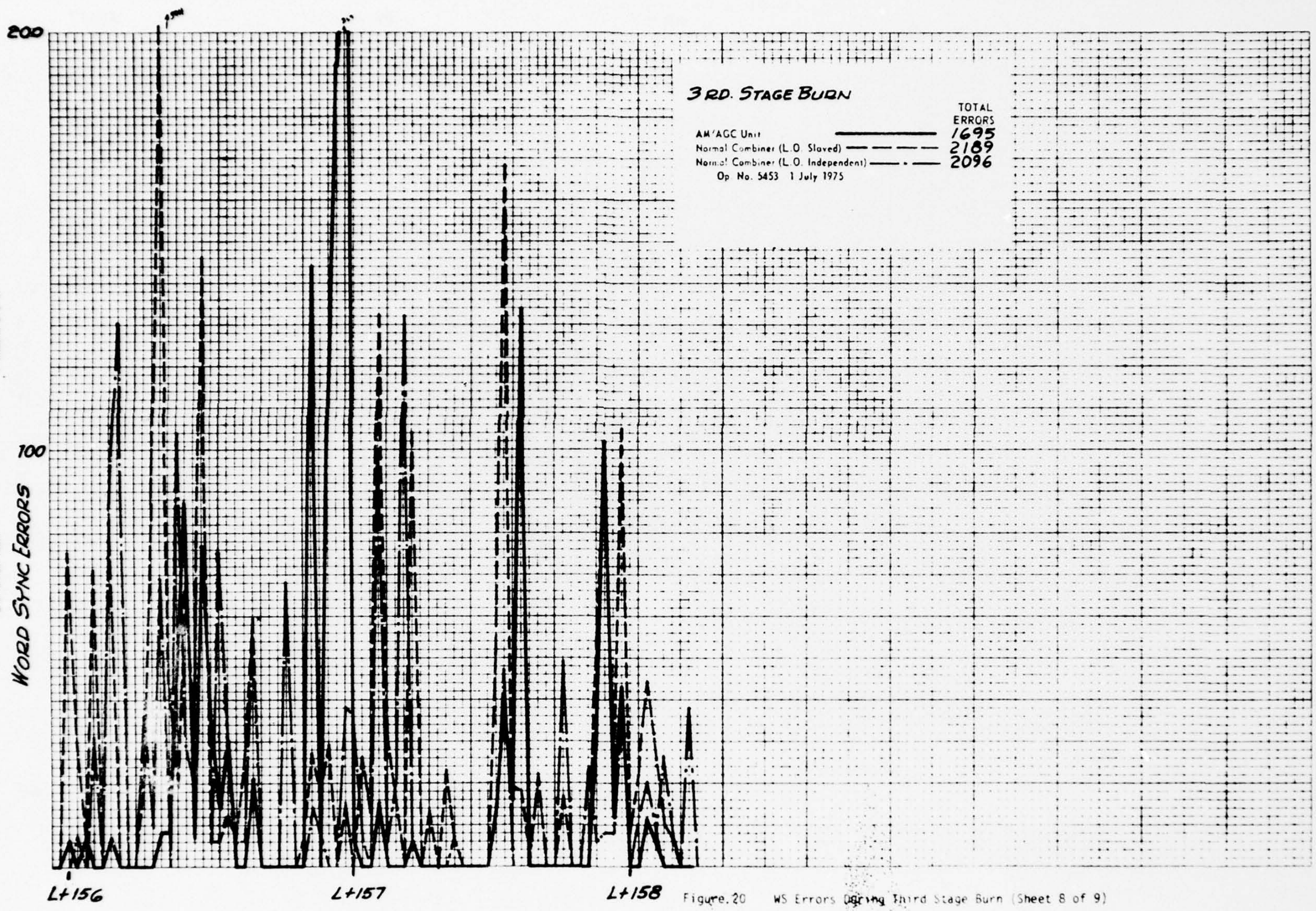


Figure 20 WS Errors During Third Stage Burn (Sheet 8 of 9)

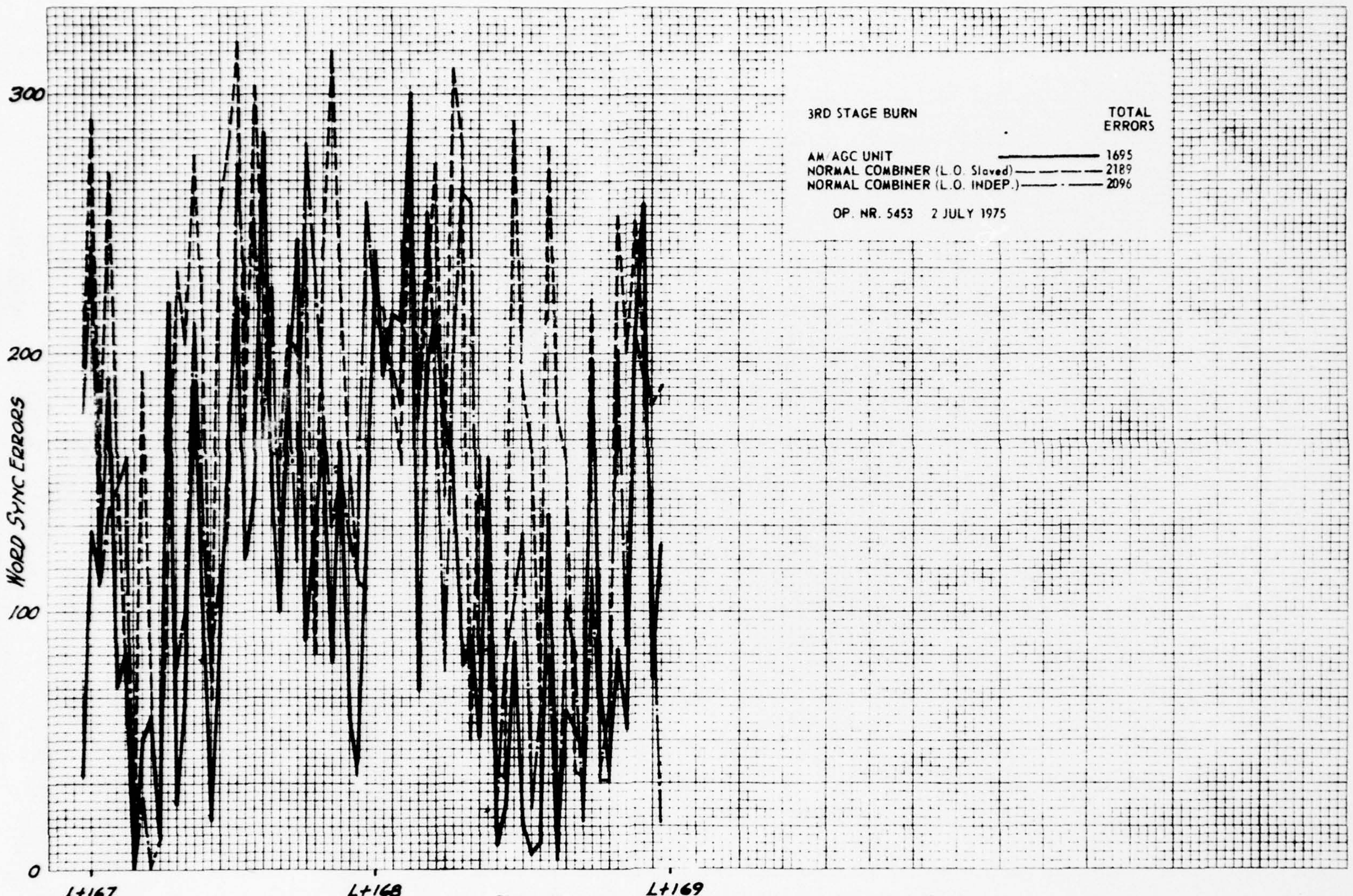


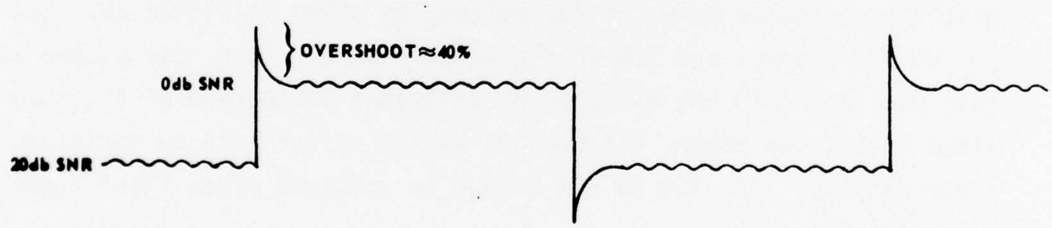
Figure 21 WS Errors During Third Stage Burn (Sheet 9 of 9)

4.0 AM/AGC TECHNIQUE LIMITATIONS

4.1 AM/AGC Interface Unit

Figure 22 is a sketch of the AM/AGC interface unit AGC output that directly controls the combiner weighting action. The voltage step is in response to a 20 db change in RF level at the receiver input. This figure points out the overshoot due to the AM detector and filter circuitry. At low SNR the AGC level is near -0.5V. This overshoot can then cause a positive control voltage to the combiner. References 3 and 4 show that the Microdyne Model 3300-C combiner will select the wrong receiver channel if it receives positive control voltages.

Figure 23 is a sketch of unequal RCP and LCP signal levels where the AM detector overshoot could again cause degradation. The effects of the overshoot were lessened for Operation 5453 by setting the AGC voltage more negative.



Note: 0 db SNR = -0.5V AGC Voltage
20 db SNR = -2.5V AGC Voltage
Upper overshoot peak ≃ +0.3V AGC Voltage

Figure 22. AM/AGC Interface Unit Control Voltage Output During 20 db RF Level Changes

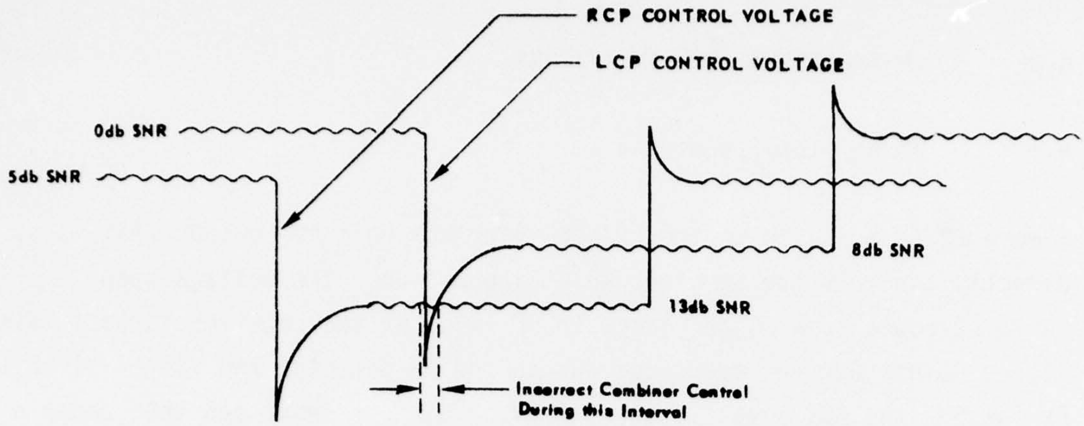


Figure 23. AM/AGC Control During Unequal Level Alternate Channel Fading

The 30 KHz low pass filter (LPF) following the AM detector limits the control voltage response time to .03 ms for 20 db RF signal changes. This response time is an order of magnitude slower than the speed at which the combiner can switch from one channel to the other.

4.2 Model 3300-C(A) Combiner

Since the predetection and post-detection switching circuitry of the combiner are the same, a simple switching rate response test was devised utilizing a square wave control voltage as shown in Figure 24. With no input to one channel and PCM on the other channel input, the square wave rate was set at 10 KHz while an oscilloscope photograph of the combined video output was taken. Figures 25 and 26 differ only in horizontal scale display. The 10% to 90% change in combined video level requires approximately 4 μs.

To verify the switching rate, a BER count was taken at various square wave rates. Above 90 KHz switching rates the BER remained at zero errors since the combiner was unable to switch. At 90 KHz or lower an overflow of errors occurred because the channel with no input was correctly selected. These tests were performed at bit rates of 1 MBs, 500 KBs, 100 KBs and 10 KBs with the same results in every case. The data could be on either input and produce the same results.

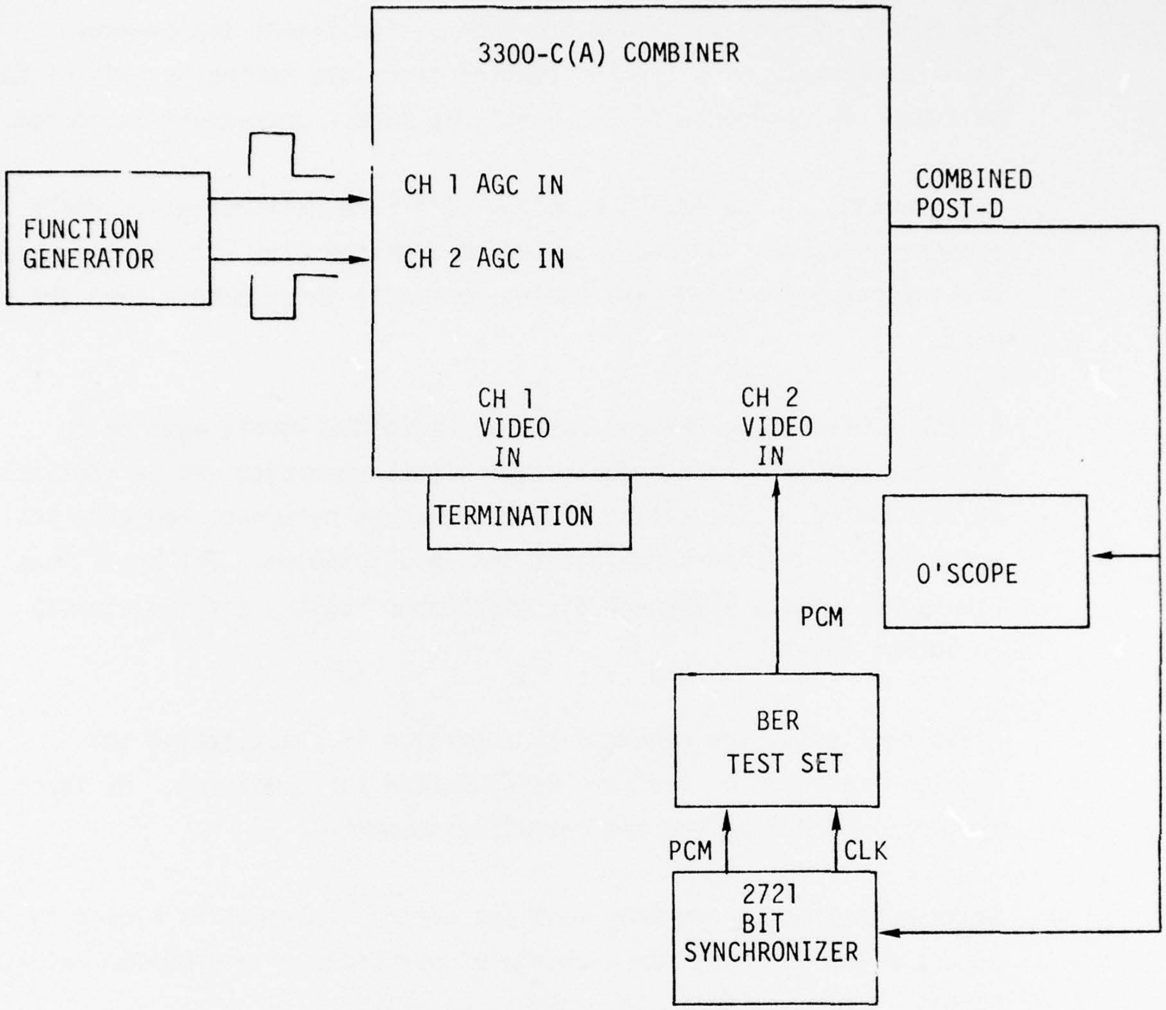


FIGURE 24. Combiner Switching Rate Test Configuration

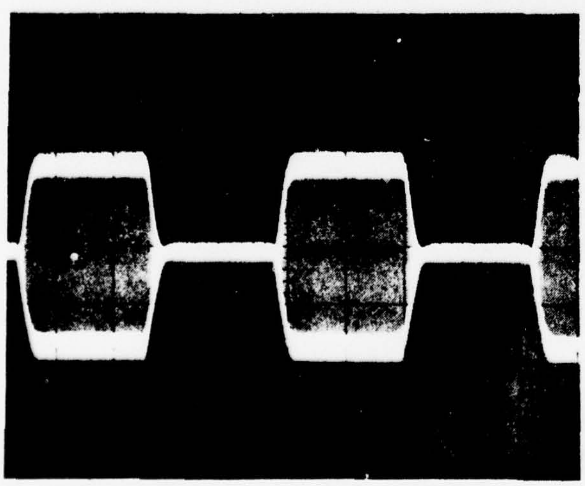


FIGURE 25. COMBINED VIDEO (HORIZONTAL SCALE=20μS/DIV)

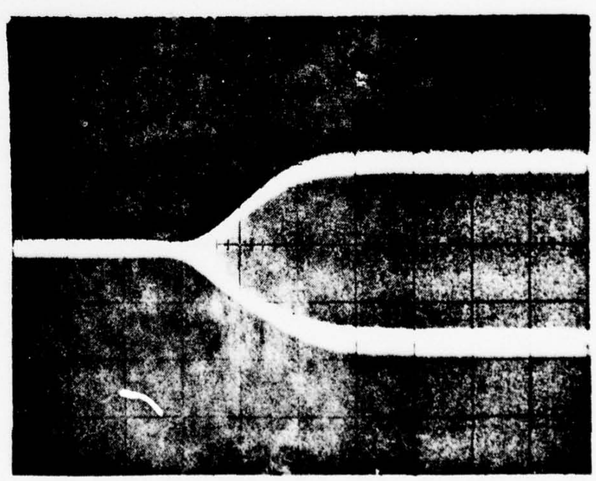


FIGURE 26. COMBINED VIDEO (HORIZONTAL SCALE=2μS/DIV)

5.0 CONCLUSIONS

The AM/AGC control technique provided a significant improvement in data recovery over the AGC control technique during periods of heavy multipath interference of the Minuteman launch operations supported.

Improvements of the AM/AGC Combiner Interface Unit circuitry which prevent overshoot and decrease the AM detector plus LPF response time will provide more recovered data during multipath interference than the existing unit.

A method of setting the receiver linear 10 MHz levels must be provided before linear predetection signal combining can be routinely used at the SAMTEC. Discussions with maintenance personnel indicate that the Model 1100-R receivers represent the worst problem. The newer Model 2200-R receivers contain different distribution circuitry and are closely matched in output level.

Additional tests are required to determine if phaselocking the receiver second L.O.'s offers an advantage for combining. No improvement was measured during the one operation supported.

Standardization of combiner test set control voltages is needed to create a common basis for exchange of performance information between test ranges. This action is in progress by IRIG.

6.0 RECOMMENDATIONS

Modify the AM detector and LPF circuitry of the AM/AGC Combiner Interface Unit to eliminate overshoot and reduce response time; then retest the unit.

Investigate methods of setting the linear 10 MHz receiver output levels so that linear predetection can be implemented at the SAMTEC.

Perform additional combiner tests with the receiver second L.O.'s slaved.

Obtain copies of the Diversity Signal Characterization Unit (DSCU) test evaluation from PMTC for SAMTEC use. Use of this equipment at Kwajalein Missile Range should be made as soon as possible since transmission of RF signals during reentry is the area where the greatest loss of data occurs. Definition of the signal interference could result in methods of data recovery.

REFERENCES

1. "Time Domain Analysis of an AGC Weighted Combiner," E. R. Hill, 1973 International Telemetering Conference Proceedings.

2. "Space Ground Link Subsystem Baseline Test Report," Telemetry & Data Support Systems Analysis Department, Report No. P100-73-31, Sept. 1973.

3. "Diversity Combiner Test Program, Part II," T&DSSAD, Report No. P100-72-45, Oct. 1972.

4. "Diversity Combiner Test Program Report," T&DSSAD, Report No. P100-72-27, Aug. 1972.

APPENDIX A

"AM/AGC RECEIVER-COMBINER INTERFACE,"

E. R. Hill

25 November 1974

Naval Missile Center, Pt. Mugu

AM/AGC RECEIVER-COMBINER INTERFACE

E. R. Hill
25 November 1974

Naval Missile Center, Pt. Mugu

A method has been developed for improving the performance of diversity signal combiners by utilizing both the AM detected IF signals and AGC voltages from the telemetry receivers to weight the combiner. This method was first described in a paper entitled, Time Domain Analysis of An AGC Weighted Combiner, by E. R. Hill, at the 1973 ITC (International Telemetering Conference). The paper showed the performance degradation of conventional AGC-weighted combiners as a function of RF fade rate. The paper also showed a possible implementation for modification of existing AGC-weighted combiners (page 494 of the 1973 ITC Proceedings) to improve performance by using a combination of AM and AGC voltages.

An experimental design has been completed to evaluate this concept, and an engineering model of the "AM/AGC Receiver-Combiner Interface" has been constructed. The following is a brief description of the device: Figure 1 shows a schematic diagram of the unit, as well as interconnections with the telemetry receivers and the diversity combiner. The linear (non-limited) IF signal from each receiver is divided by a power divider immediately after being applied to the interface unit. One output of the power divider goes directly through the interface unit and is applied to the combiner. The second output of the power divider is applied to an AM detector. AM detectors are included in the interface unit, because those included in telemetry receivers often do not have sufficient dynamic range. The AM detectors included in the interface unit are product detectors (or synchronous detectors), and have a sensitivity of about 1 millivolt and a dynamic range of greater than 30 dB.

The AM detector is followed by a 3 pole active low-pass Butterworth Filter with a band-width (-3dB) of 30kHz. The DC logarithmic amplifier has an internal reference current of 10 μa. The 100K pot in series with the input will allow the unit to accomodate receiver output signals from about 25 to 65 MV RMS. The output of the logarithmic amplifier is added in proper proportions to the AGC voltage in a noninverting operational amplifier circuit, to obtain the improved weighting signal for the combiner. To simplify initial adjustment, the interface unit has been designed for a receiver AGC slope of 100 MV per dB. This corresponds to a value of 2 for K_1 in equation (35) of the afore mentioned ITC paper. This causes the optimum combining ratio in equation (35) to reduce to

$$a_R = 10^{(e_{W2} - e_{W1})} \qquad (1)$$

where e_{W1} and e_{W2} are the optimum weighting signals given by

$$e_{W1} = e_{g1} - \text{LOG} \frac{e_{a1}}{V} \tag{2}$$

$$e_{W2} = e_{g2} - \text{LOG} \frac{e_{a2}}{V} \tag{3}$$

They are identified on the interface chassis as AGC1 and AGC2 outputs, to correspond with the combiner input notation. The symbols not identified are the same as used in the ITC paper. The interface circuitry associated with receiver channel #2 is not shown, but is identical to that of channel #1.

A selector switch and digital panel meter (DPM) are provided on the front of the interface chassis for ease of initial set-up of both the receivers and the interface unit. Only one adjustment of the interface unit is necessary to adapt it to the particular receiver used, and that is to set the log amp outputs to zero with a strong, static RF input signal. This should be done with an RF input 20 to 30 dB above that which produces an IF SNR of 0dB. The log amp outputs are set to zero by pots labeled "AM1" and "AM2" on the front of the interface chassis, using the DPM and selector switch. The only other requirement is to adjust the receiver AGC slopes to 100 MV/dB.

A third output (for each receiver channel) is provided which is proportional to the logarithm of the RF signal level, with respect to that RF level corresponding to zero AGC voltage. This output is scaled to be equal to the AGC voltage which is produced when the AGC system tracks the changes in RF input signal level without error. It was shown in equation (37) of the ITC paper that the RF signal level could be expressed as a function of the AM and AGC voltages. For $K_1 = 2$ this equation can be written in the form

$$e_{SL} = -2 \text{ LOG} \frac{e_s}{1/K_2} = e_g - 2 \text{ LOG} \frac{e_a}{V} \tag{4}$$

where $1/K_2$ is the RF level corresponding to zero AGC voltage and e_{SL} is the analog voltage at the output of the interface unit. The first two terms of equation (4) can be written as

$$-10\, e_{SL} = 20 \text{ LOG} \frac{e_s}{1/K_2} \tag{5}$$

Which shows that the RF signal level expressed in dB with respect to $1/K_2$ is given by multiplying e_{SL} by -10.

Tests are being conducted to evaluate the performance of a diverstiy combining system, using the "AM/AGC Receiver-Combiner Interface" unit, under laboratory conditions. Initial test results indicated a significant performance improvement under conditions of rapid fading RF signals, but comprehensive testing will have to be completed before definite conclusions can be reached.

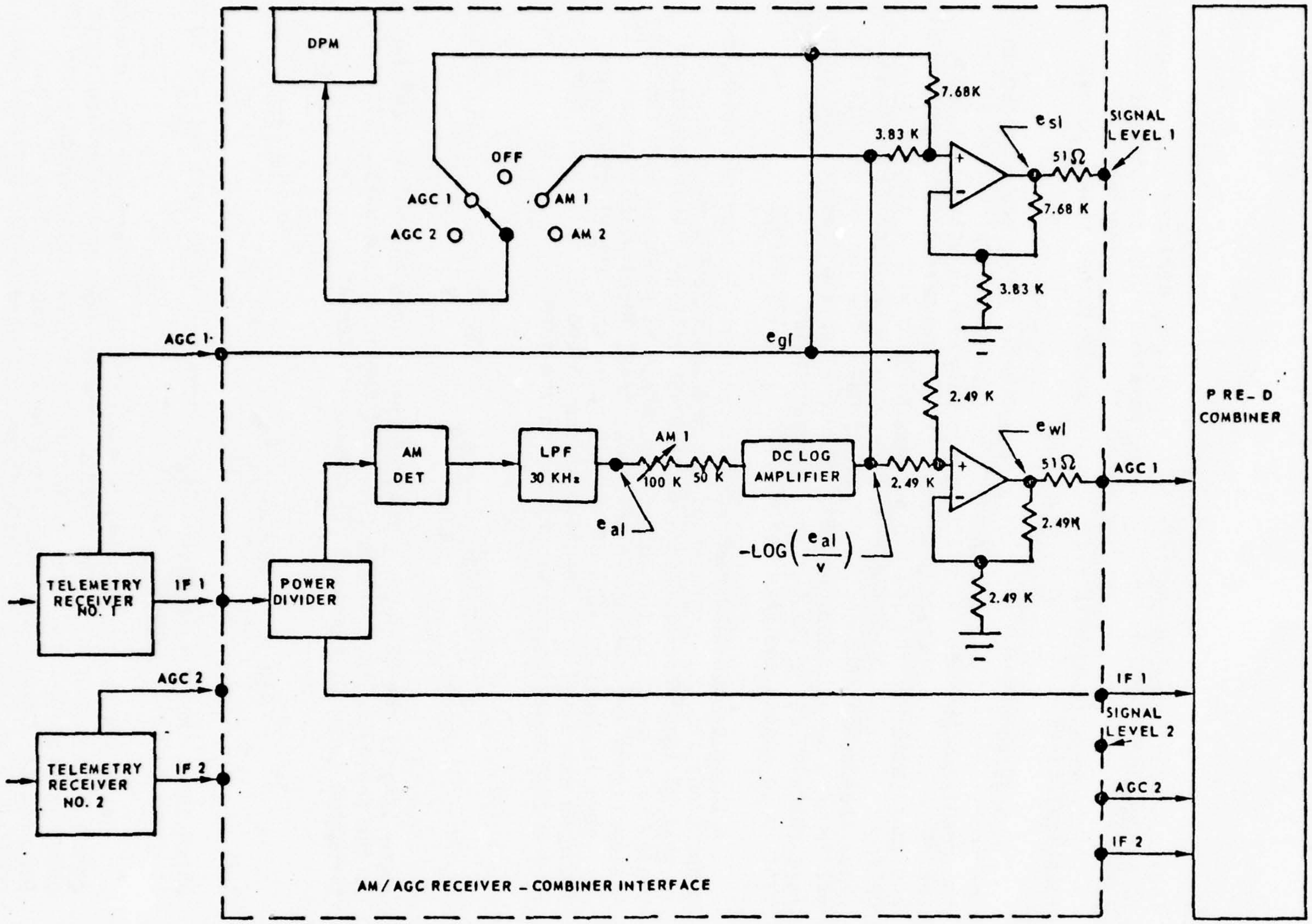


FIGURE I EXTERNAL MODIFICATION OF A CONVENTIONAL AGC WEIGHTED COMBINER

27 Jan 1975

E. R. Hill

Addendum to "AM/AGC Receiver-Combiner Interface"

This note supplements the report, "AM/AGC Receiver-Combiner Interface" submitted 25 November 1974 by E. R. Hill. It provides additional information that may be desired by an uninitiated user.

The schematic diagram in Figure 1 shows all circuit details except the AM detector and the low pass filter. Details of the AM detector and the low pass filter appear in Figure 2. The 7-35pf trimmer capacitor which appears in series with the input to the MC1590 limiter in Figure 2 is used to phase align the carrier and signal inputs to the MC1596 double balanced modulator. The 820-pf capacitor across the output terminals of the MC1596 places a pole at 100 kHz for pre-filtering ahead of the differential amplifier and active low pass filter.

The AM detector as implemented in Figure 2 produces an output proportional to the average absolute value of signal plus noise. This AM detector approximates a coherent AM detector down to IF signal-to-noise ratios of approximately unity (OdB). Figure 3 shows the theoretical performance of this type of AM detector as well as the actual performance of the AM detectors included in the Interface chassis. The output (ordinate) in Figure 3 is normalized by dividing by the average absolute value of the signal.

Performance is also limited by the frequency response of the DC log amplifier. The bandwidth of a nonlinear device of this type is hard to specify definitively, however, measurements have shown that the frequency

volt change in AGC voltage for a change in IF SNR from +6db to +16db.

(3-9)f. Use linear IF outputs.

Combiner Adjustments

(3-10)c. Set switch to "logic disable".

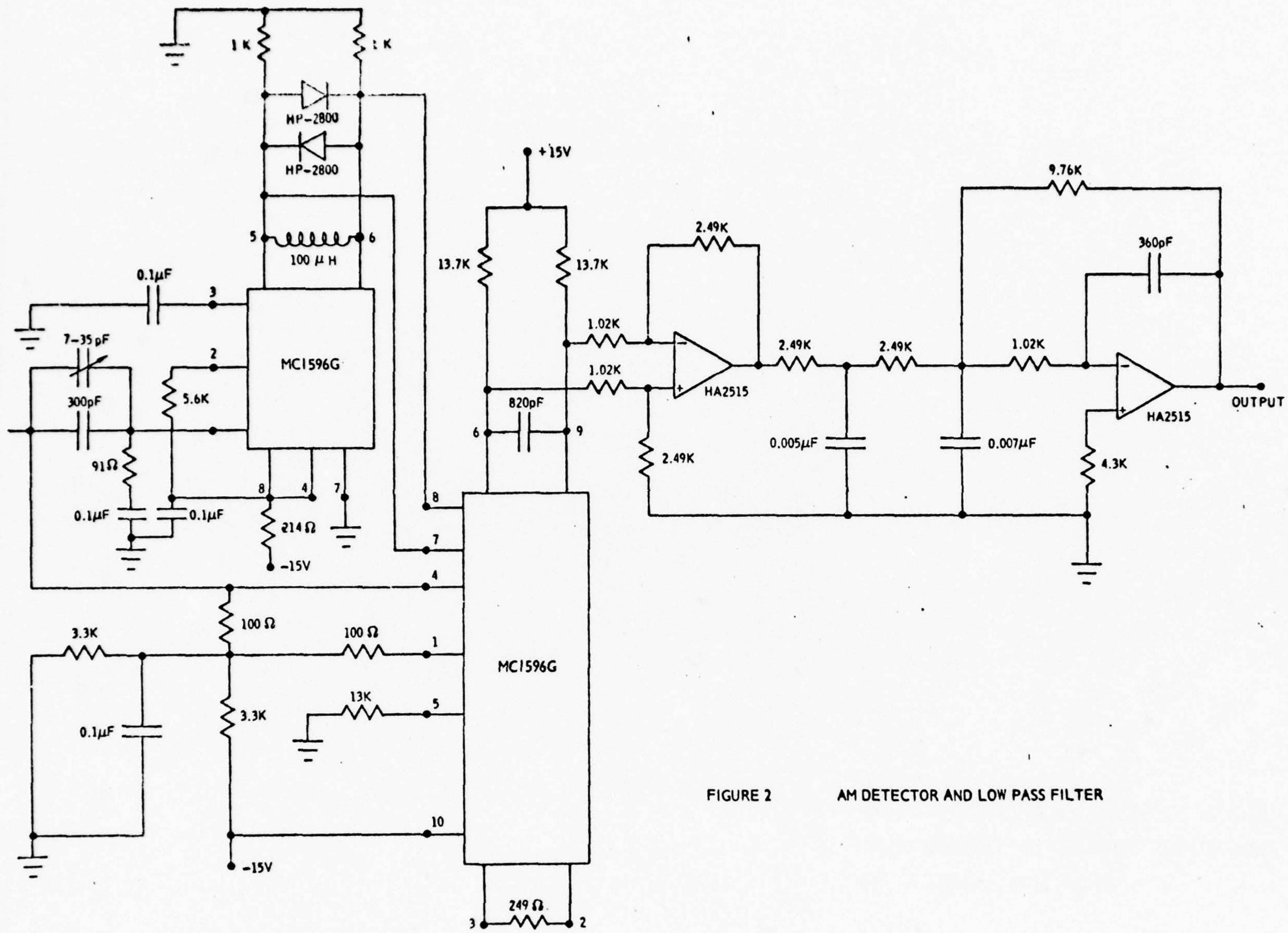


FIGURE 2 AM DETECTOR AND LOW PASS FILTER

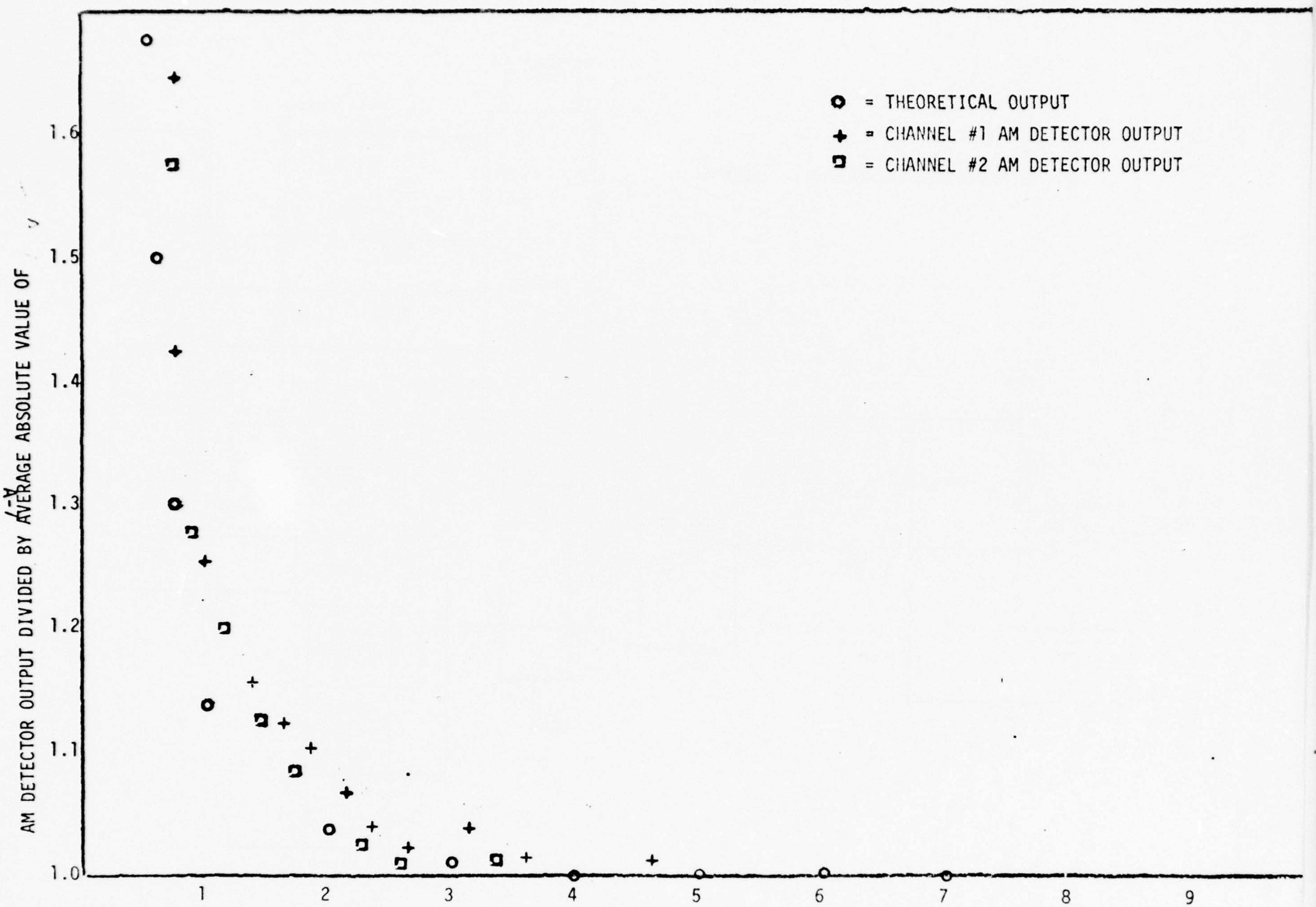


FIGURE #3 IF SNR (RMS D/RKS NOISE)

APPENDIX D

PRELIMINARY REPORT ON THE

DIVERSITY COMBINER AM/AGC

CONTROL TECHNIQUE

21 SEPT 1976

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

1.1 This preliminary report is published in response to SAMTEC Performance Analysis Task A 6141 which directs the test and evaluation of the AM/AGC Receiver - Combiner Interface Unit Phase II. This report presents information on operational verification test results obtained with a multipath simulation test set and data recorded during missile launch operations.

1.2 The Pacific Missile Test Center (PMTC), responding to a task from the Range Commanders Council Telemetry Group, designed, fabricated and lab tested a circuit that would utilize the AM detected IF signals and AGC voltages from the telemetry receivers to control the diversity combiner. The Phase II Interface Unit which is analyzed herein incorporates the recommended modifications from the first Performance Analysis Department investigation. (Reference PAD report "AM/AGC Receiver Combiner Interface" (phase 1) dated 25 November 1974.) A detailed description of the AM/AGC Receiver Combiner Interface Unit is contained in Appendix A.

1.3 The advantage of the AM/AGC Interface Unit is the ability of its AM detector to follow rapid radio frequency (RF) fluctuations which the relatively slow receiver AGC circuitry does not respond to. The purpose of the interface unit is to provide control signals to the combiner which correspond to the fluctuations. Operational verification tests were conducted to demonstrate that the Interface Unit does produce faster channel selection during alternate channel fading.

1.4 Telemetry data recorded during several Minuteman launch operations showed that the combiner controlled by the AM/AGC Receiver Combiner Interface Unit (AGC "comb" output) was able to retrieve some additional data not obtained by the normal AGC controlled combiner during the rapid fade conditions of third stage burn of the Minuteman III missile. All available data used in this report preparation has been sent to the Pacific Missile Test Center for its evaluation. The test data includes data recorded with the PMTC Diversity Signal Characterization Unit (DSCU) which was not a part of this analysis. The DSCU measures the phase difference between the two receive channels plus the amplitude of the carrier envelope on each channel. This output data was then frequency modulated on separate 450 Khz carriers and recorded on analog magnetic tape.

2.0 OBJECTIVES

2.1 The objectives of the tests and analysis reported herein are:

a. To determine whether or not the AM/AGC Receiver Combiner Unit will improve combiner channel selection during rapid alternating channel fade conditions.

b. To measure any improvement in data recovery contributed by the Interface Unit over that of a standard AGC controlled combiner during the multipath conditions of a missile launch operation.

c. To determine the limiting performance factors associated with the AM/AGC Receiver Combiner Interface Unit control technique.

3.0 TEST AND TESTS RESULTS

3.1 Dynamic Alternate Right Hand (RH) and Left Hand (LH) Channel Fade Test

3.1.1 With the equipment configured as shown in Figure 1 the control voltages of each function generator output were adjusted to simulate alternate RH and LF channel fading. The initial part of the test program was to determine which receiver AGC time constant and combiner AGC slope provide the best data under dynamic fading conditions.

3.1.2 The test results may be summarized as follows:

a) At low fade rates (50 to 100 Hz) with the receiver time constant set at 0.1 millisecond, fade depths of 15 to 20 db and an IF signal to noise ratio (SNR) of 10 db, the Microdyne Model 1100-R receiver leveling circuitry responds incorrectly, i.e., the envelope of the IF signal is largest during noise and smallest during signal. This higher signal level during noise causes an incorrect voltage to be summed with the receiver AGC. See Figure 2.

b) With the receiver AGC time constant set at 0.1 millisecond, the receiver AGC lags the actual RF signal nulls. See Figure 2. This AGC voltage is then summed with the 10 MHz detected AM. Figure 4 shows that the control voltage from the AM/AGC unit still lags the actual RF nulls.

c) The receiver AGC time constant was set to 10 millisecond and to 1 second. At these low AGC settings the receiver AGC will indicate an average signal level which is summed with the detected AM from the linear 10 MHz. Figure 5a shows the control voltage from the AM/AGC Interface Unit with no receiver AGC input. The receiver AGC time constant was 0.1 milliseconds and fade rates were approximately 1.5 KHz. It is interesting to note that the receiver AGC has a definite effect on the linear 10 MHz envelope. Figure 5b shows an ideal control voltage. The receiver AGC time constant was 1 second and fade rates were approximately 2 KHz. The receiver AGC was not connected to the AM/AGC Interface Unit. Also note that the linear 10 MHz signal responds ideally to the incoming RF levels. Figures 6a and 6b show that the AM/AGC Interface Unit control voltage with the receiver AGC time constant set at 0.1 millisecond and 1 second respectively. The comparison of the two figures shows that the best receiver AGC time constant setting, using the AM/AGC Interface Unit, is the 1 second setting.

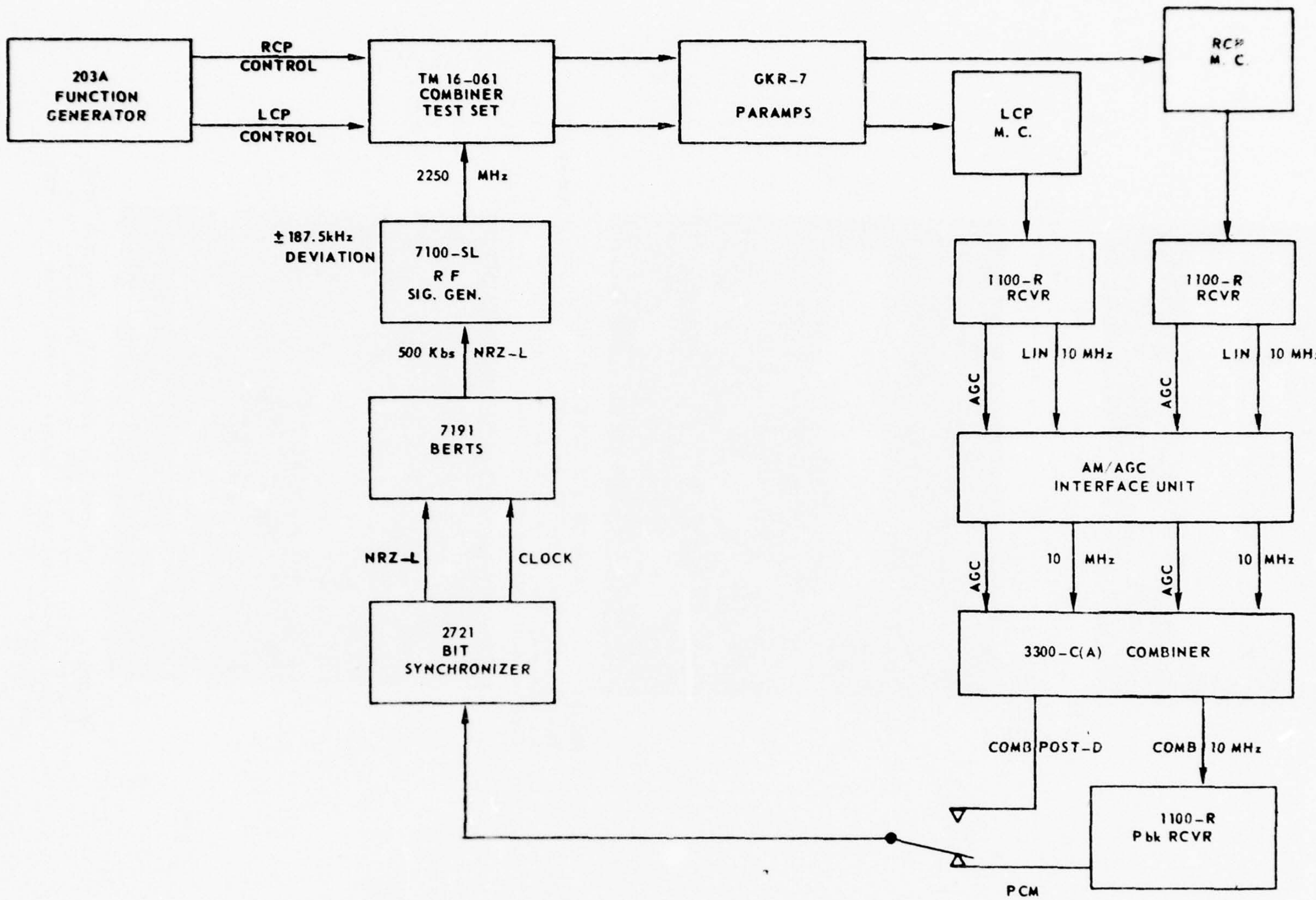


FIGURE 1 OPERATIONAL VERIFICATION TEST CONFIGURATION

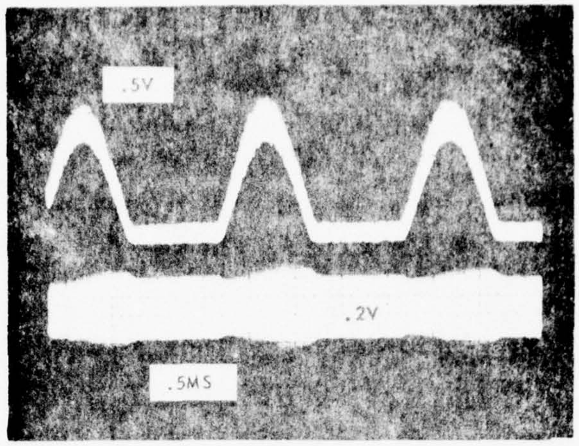


FIGURE 2 AM/AGC CONTROL VOLTAGE AND 10MHz RF
The top trace shows the control voltage from the AM/AGC unit. The bottom trace shows the 10MHz signal from the receiver. Fade rates were 100Hz.

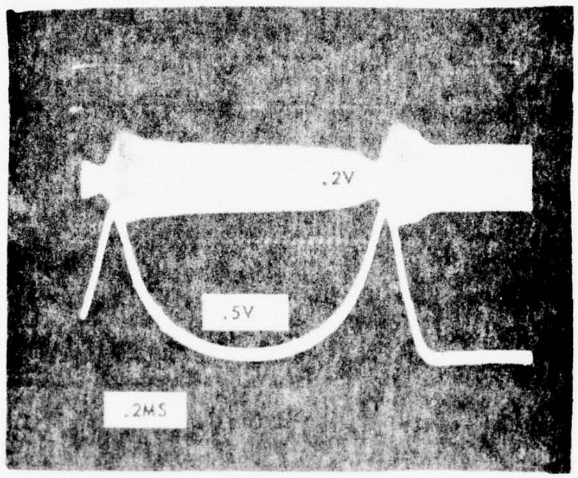


FIGURE 3 10MHz RF AND RECEIVER AGC
The top trace shows the RF envelope. The bottom trace shows the AGC from the receiver. Fade rates were 300Hz. Receiver AGC time constant at 0.1ms.

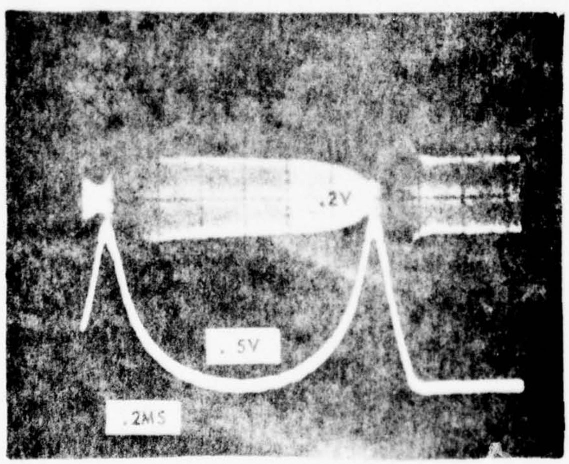


FIGURE 4 10MHz RF AND AM/AGC CONTROL VOLTAGE
The top trace shows the RF envelope. The bottom trace shows the AM plus AGC. Fades and receiver setting same as Figure 3.

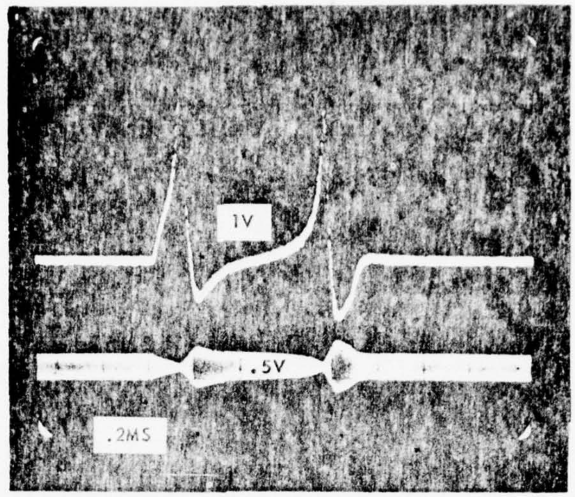


FIGURE 5a AM/AGC LOG AMP. OUTPUT AND 10MHz RF
The top trace shows the detected AM output from the log amplifier. The bottom trace shows the 10MHz signal. Receiver AGC time constant at 0.1 sec.

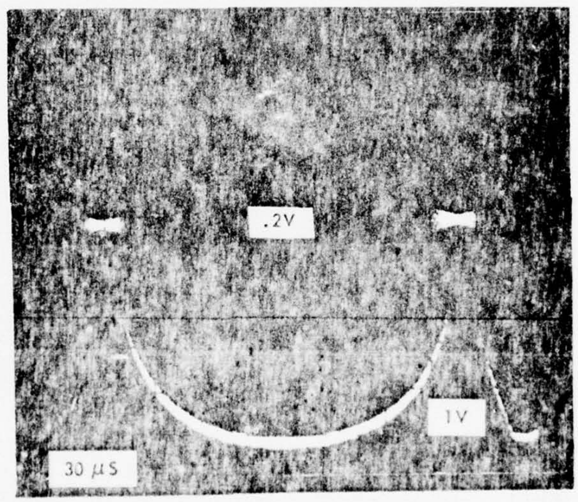


FIGURE 5b 10 MHz RF AND AM/AGC LOG AMP. OUTPUT
The top trace shows the 10MHz signal. The bottom trace shows the detected AM output from the log amplifier. Recever A G C time constant at 1 sec.

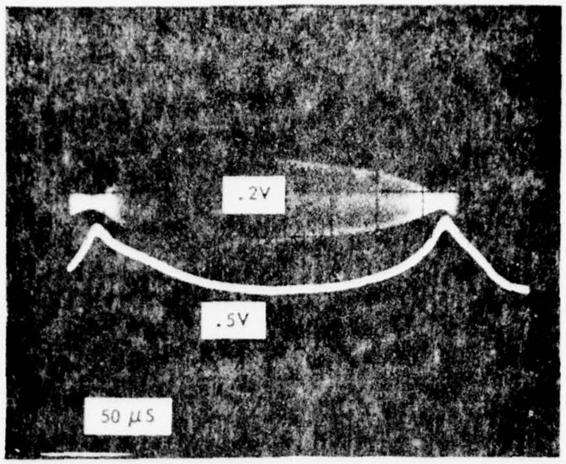


FIGURE 6a 10MHz RF AND AM/AGC CONTROL VOLTAGE
The top trace is the RF signal. The bottom trace is the AGC output from the AM/AGC unit. Receiver AGC time constant was set at 0.1Msec. Fade rates were 1KHz.

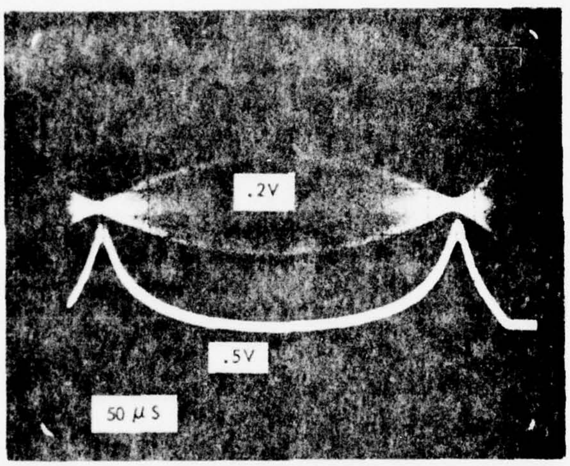


FIGURE 6b 10MHz RF AND AM/AGC CONTROL VOLTAGE
The top trace is the RF signal. The bottom trace is the AGC output from the AM/AGC unit. Receiver AGC time constant was set at 1 second. Fade rates were 1 kHz

3.1.3 Table I shows the results of the dynamic tests using receiver time constants of 0.1 millisecond and 1 second. Both the IRIG and SAMTEC control voltages to the combiner test set were used. The initial test conditions were:

a) Signal generator level was set to establish a BER of 1×10^{-5} on a single channel.

b) The combined output was checked to insure a BER of 1×10^{-6} or greater to confirm that the combiner provided SNR improvement under steady state conditions.

c) Combiner AGC slope settings are different for the two outputs ("combine" and "select") from the AM/AGC unit. The combiner using the "combine" output was set up on 3db SNR for zero and 20db SNR for 1 volt dc on the AGC scale. The combiner using the select output was set up on -47 dbm and -107 dbm (preamplifier input level) per site procedure.

Test results indicated that these combiner settings for the different outputs from the AM/AGC unit provide the best BER. The test data shows that the best receiver AGC time constant using the "combine" AGC output to control the combiner was at 1 second and 0.1 millisecond using the "select" control voltage to the combiner.

3.1.4 Fade rates above 1 KHz could not be obtained from either the "combine" or the "select" output from the AM/AGC unit. It was found that at approximately 2 to 2.5 KHz above the first break point the BER's settle back 5×10^{-5} BER. At this point the fade rates obtained were up to 20 KHz. This implies that the loop bandwidth of the phase lock loop (PLL) in the Microdyne combiner loses lock during fast switching transitions. Therefore, when the switching or channel selection exceed 1 KHz the BER increases and as the fade rate increases from 1 KHz to the second point, the BER settles back again because the loop bandwidth of the PLL can not react fast enough to go into a search mode. Similar results were obtained by PMTC personnel.

3.1.5 The following figures show the receiver AGC responses caused by the different control voltage settings on the combiner test set. Figure 7 shows the actual fade seen by the receiver when the combiner test set was adjusted to a SAMTEC control voltage. The top trace shows the RH AGC response and the

bottom trace shows the LH AGC response. Figure 8 shows the actual fade seen by the receiver using a combiner test set IRIG control voltage. The top trace is the RH Receiver AGC and the bottom trace is the LH Receiver AGC response. Figure 9 shows the actual fade seen by the receiver when the combiner test set control voltage is adjusted to create RF nulls at the top of the control voltage. The top trace shows the RH AGC response and the bottom trace shows the LH AGC response. For all cases a positive deflection indicates a decrease of signal level. (The combiner test set control voltage wave forms are shown in "Diversity Combiner AM/AGC Control Technique" Report number PA100-75-45 Figure 2 a through 2 c.)

The AM/AGC Interface Unit has been returned to PMTC for incorporation of a PMTC designed combiner circuit with wider PLL bandwidth characteristics. This unit will then be bench tested at PMTC and subsequently returned to SAMTEC for test and evaluation in the fourth quarter of 1976.

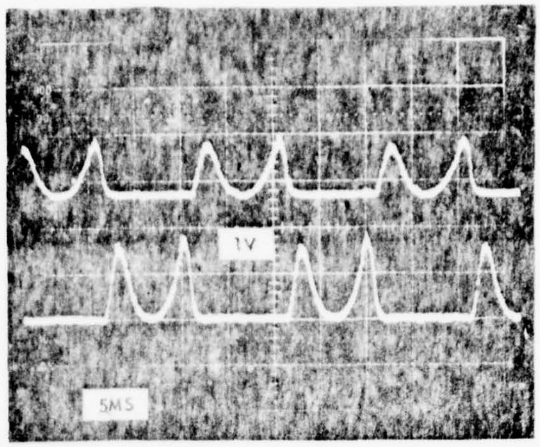


FIGURE 7 RECEIVER AGC VOLTAGE

Fades as seen by the receiver using SAMTEC control voltage. The top trace RH AGC. The bottom trace LH AGC.

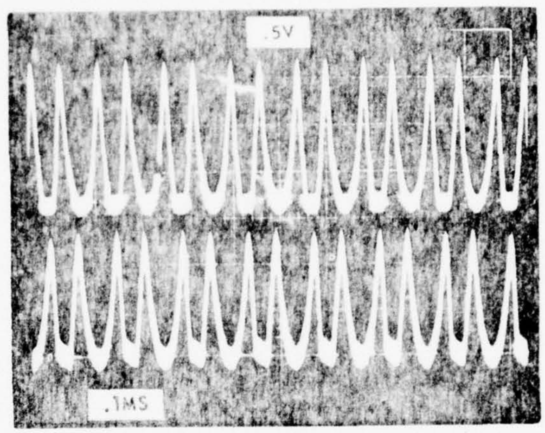


FIGURE 8 RECEIVER AGC VOLTAGE

Fades as seen by the receiver using IRIG control voltage. The bottom trace LH AGC.

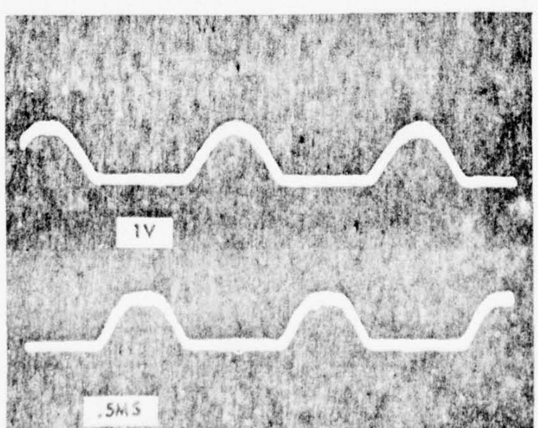


FIGURE 9 RECEIVER AGC VOLTAGE

Fades as seen by the receiver when the control voltage produces a RF null at the crest of the control voltage. The top trace RH AGC. The bottom trace LH AGC.

Table 1

Dynamic Test Results

Combiner Test Set Control Voltage	Selected AM/AGC Output	Selected RCVR AGC Time Constant	Fade Rate*
IRIG	COMB	1 sec	1 KHz
IRIG	SELECT	1 sec	≈100Hz
IRIG	SELECT	.1 ms	250Hz
SAMTEC	COMB	.1 m sec	883Hz
SAMTEC	SELECT	.1 m sec	750Hz
SAMTEC	COMB	1 sec	2KHz
SAMTEC	SELECT	1 sec	250Hz

* Fade rate value was the point at which the BER increased by two orders of magnitude

3.2 Launch Data

Five SAMTEC telemetry operations were supported with the AM/AGC Receiver Combiner Interface Unit (four missile flight test operations i.e., two Minuteman III, a Minuteman II, a Titan II and a B-1 aircraft support operation). This report analyzes data from only two of the missile launch operations i.e., a Minuteman III launch supported on 20 June 1976, which contains data from the AM/AGC "combiner" output and a normally controlled combiner and a Minuteman II launch supported on 22 June 1976 which was configured for both "select and combine" outputs from the AM/AGC Receiver Combiner Interface Unit and a normally controlled combiner.

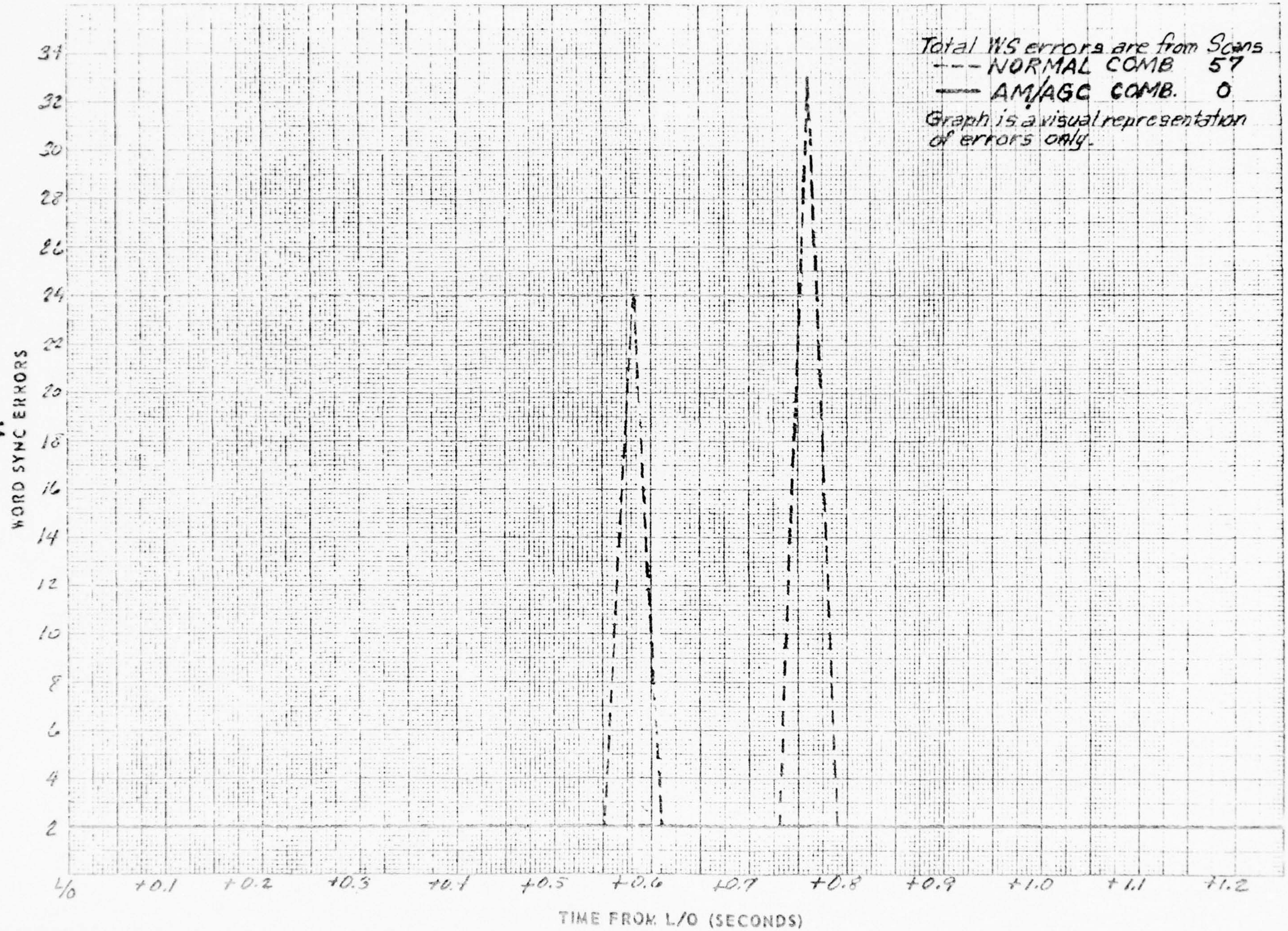
3.2.1 Launch Operation 4044

This Minuteman III launch operation conducted on 20 June 1976, provided recorded magnetic tape data of the predetection combined signals (LH and RH) from the "combine" outputs of the AM/AGC Receiver Combiner Interface and a normally controlled AGC combiner.

The Minuteman data format was PCM, Bi-Φ-L/PM. The PCM frame synchronization (FS) is 27 bits long at a repetition rate of 30 milliseconds. The word synchronization (WS) pattern is 3 bits long at a repetition rate of 78 μsec. Computer scans of every WS pattern were plotted in Figures 10 through 13. The total number of WS errors occuring during the period of flame attenuation is also annotated for each combiner.

Data degradation occured during lift-off, staging, shroud ejection, and third stage burn. Lift-off and flame noise which occurs during third stage burn provided the best opportunity to compare the performance of the two types of combiner control. Figure 10 shows that the AM/AGC controlled combiner provided error free data during lift-off period of L+0 to L+1.2 second. The normally controlled AGC combiner had 57 WS errors. The SNR recorded during this period was greater than 30 db as indicated by the signal strength records. Figure 11 shows the normally controlled combiner to have less WS errors during staging and skirt jettison. During this period signal selection is a matter of signal availability and combiner recovery. Figure 12 (23 sheets) shows WS errors during third stage burn. Figure 12, sheet 3

shows that the first part of the third stage burn period (L+128 to L+129) the AM/AGC controlled combiner provided more error free data than the normally controlled combiner. From L+129 to L+136 as shown on Figure 12 sheets 2 through 9, where the multipath is the heaviest, analyzed data indicates that the normally controlled combiner provided more error free data than the AM/AGC combiner. The data analyzed during this period indicates that the AM/AGC Interface Unit and its controlled combiner were selecting the channel with the higher signal level while the combiner PLL was not locked. During the period from L+136 to third stage thrust termination, refer to Figures 12 (sheets 8 through 23) and 13, the fade rates decreased and the SNR increased. The AM/AGC controlled combiner provided more useable data than the normally controlled combiner.



WORD SYNC ERRORS
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
L/O
+0.1
+0.2
+0.3
+0.4
+0.5
+0.6
+0.7
+0.8
+0.9
+1.0
+1.1
+1.2
TIME FROM L/O (SECONDS)
Total WS errors are from Scans
--- NORMAL COMB 57
—— AM/AGC COMB. 0
Graph is a visual representation of errors only.

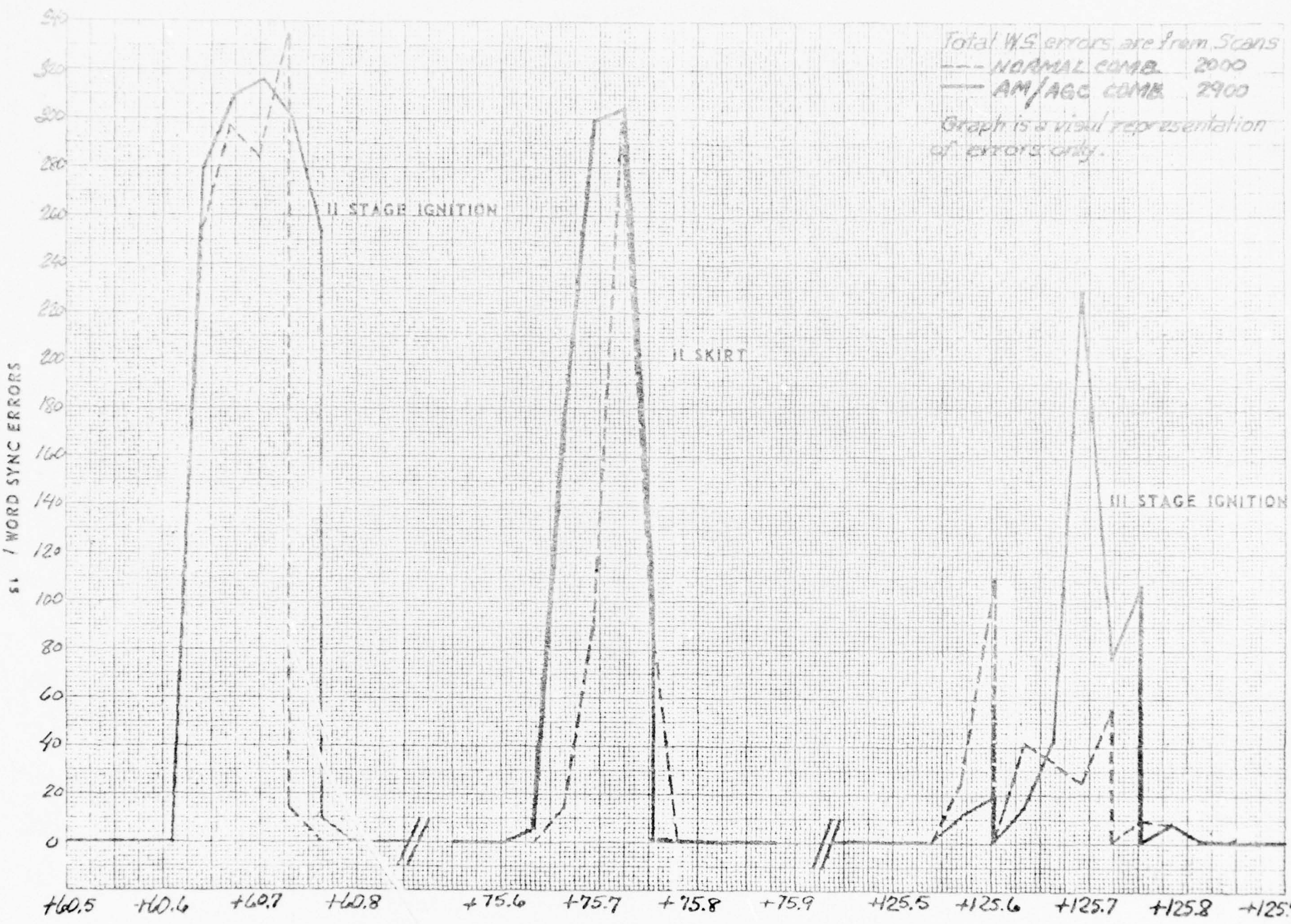
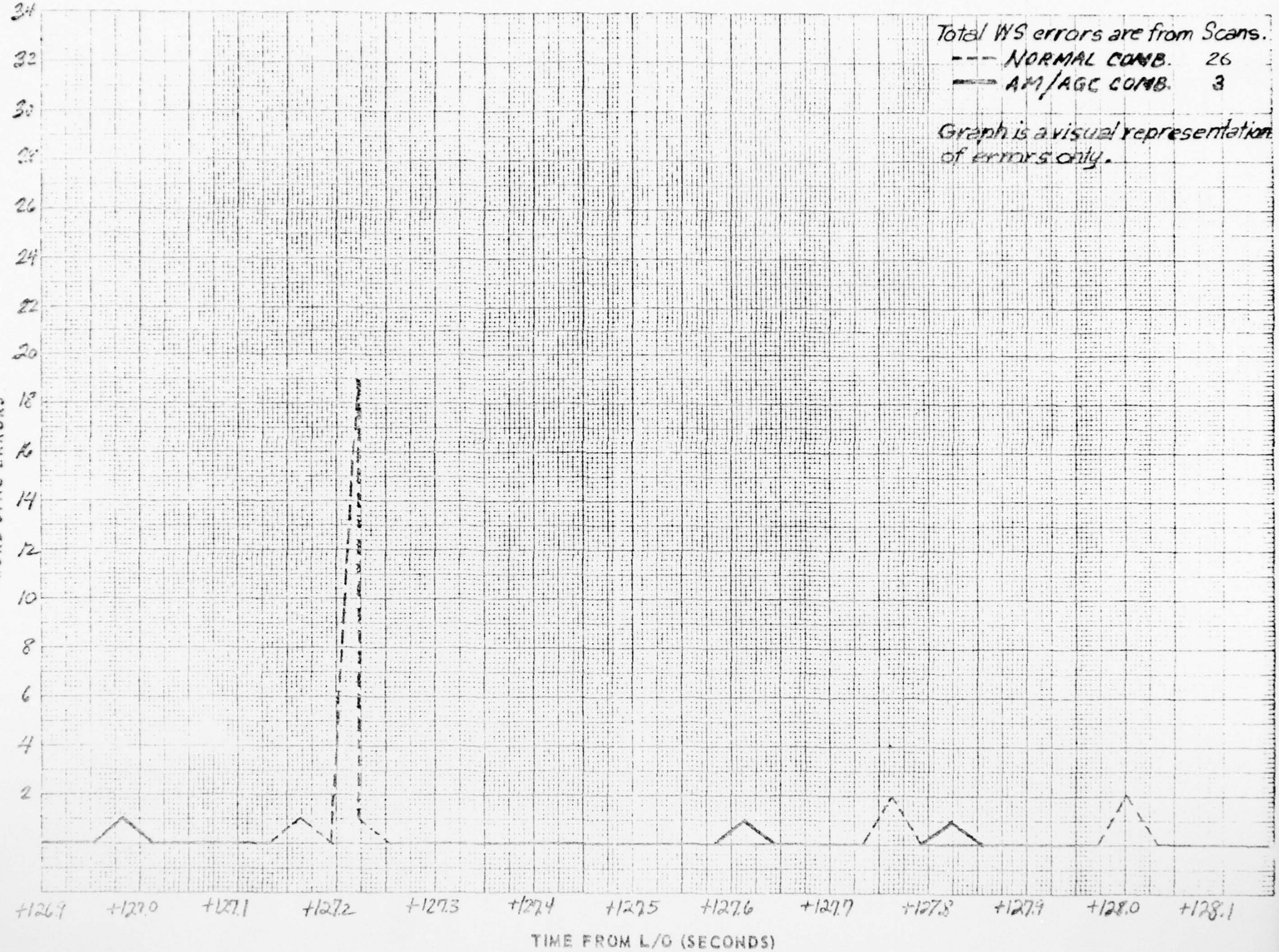


FIGURE 11 W.S. ERRORS DURING II STAGE IGNITION, II SKIRT, AND III STAGE IGNITION


Total WS errors are from Scans.
--- NORMAL COMB. 26
— AM/AGC COMB. 3
Graph is a visual representation of errors only.
WORD SYNC ERRORS
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
+126.9
+127.0
+127.1
+127.2
+127.3
+127.4
+127.5
+127.6
+127.7
+127.8
+127.9
+128.0
+128.1
TIME FROM L/O (SECONDS)

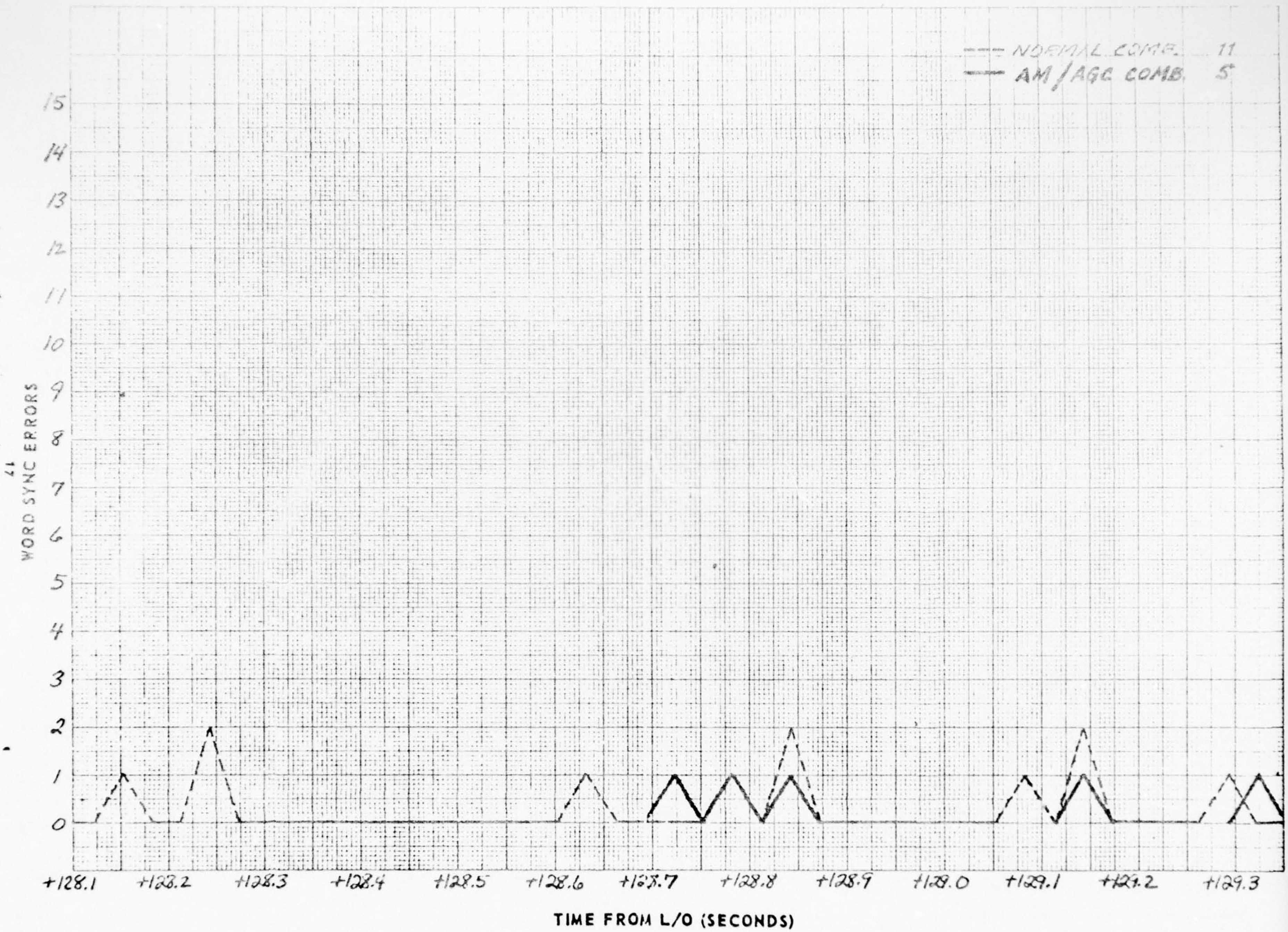
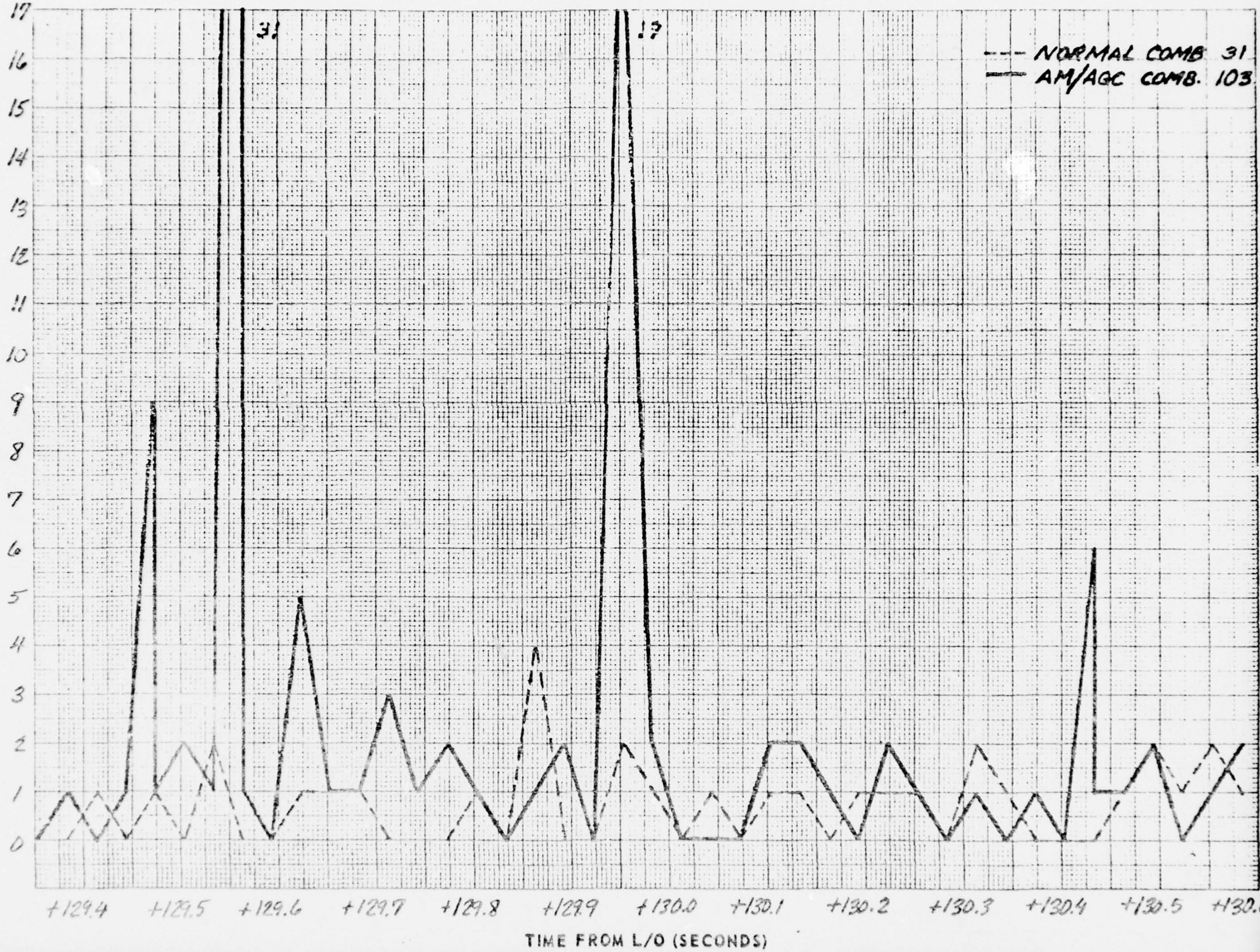


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (2 OF 23)



NORMAL COMB 31
AM/AGC COMB. 103
31
17
WORD SYNC ERRORS
TIME FROM L/O (SECONDS)

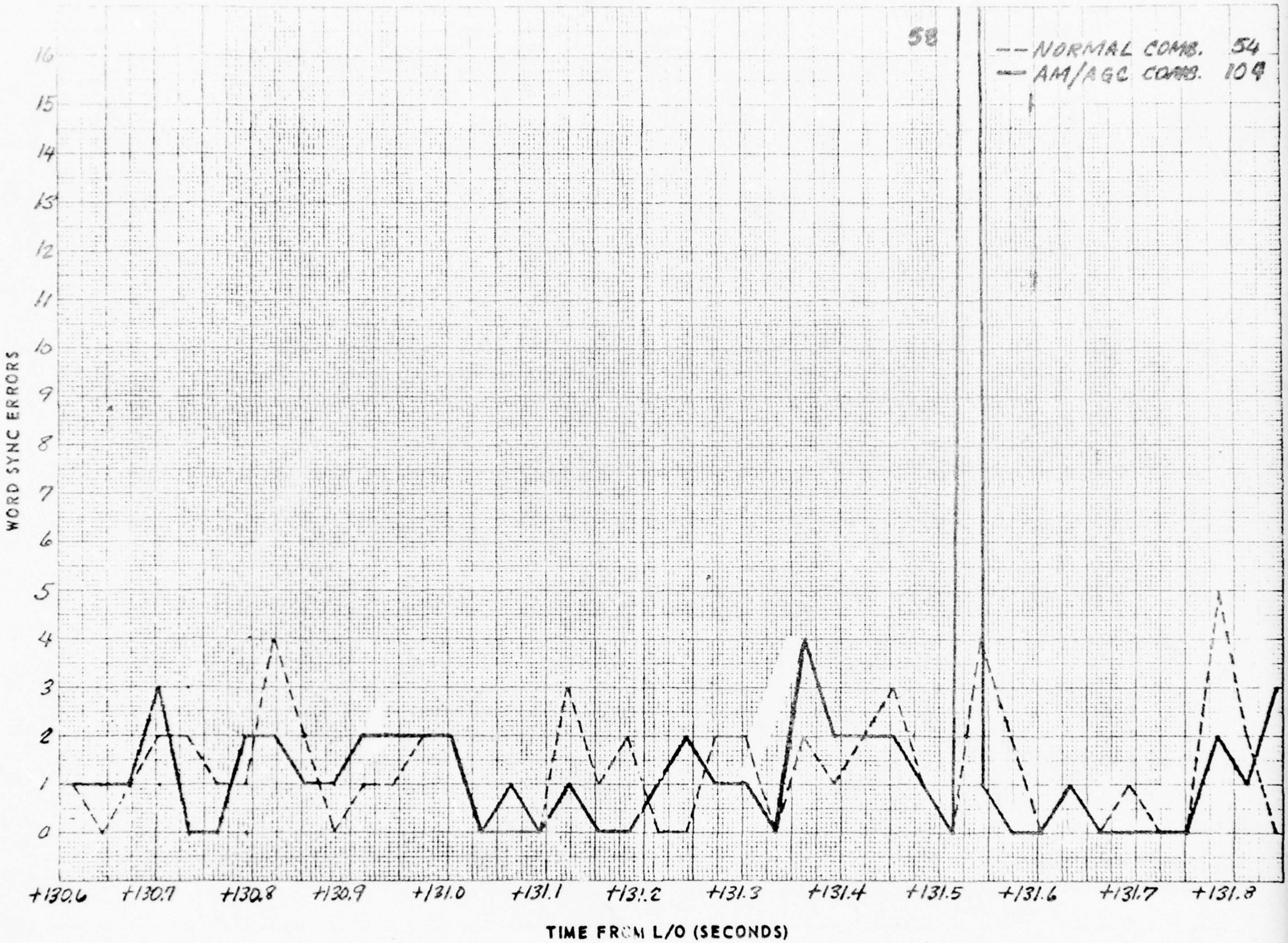
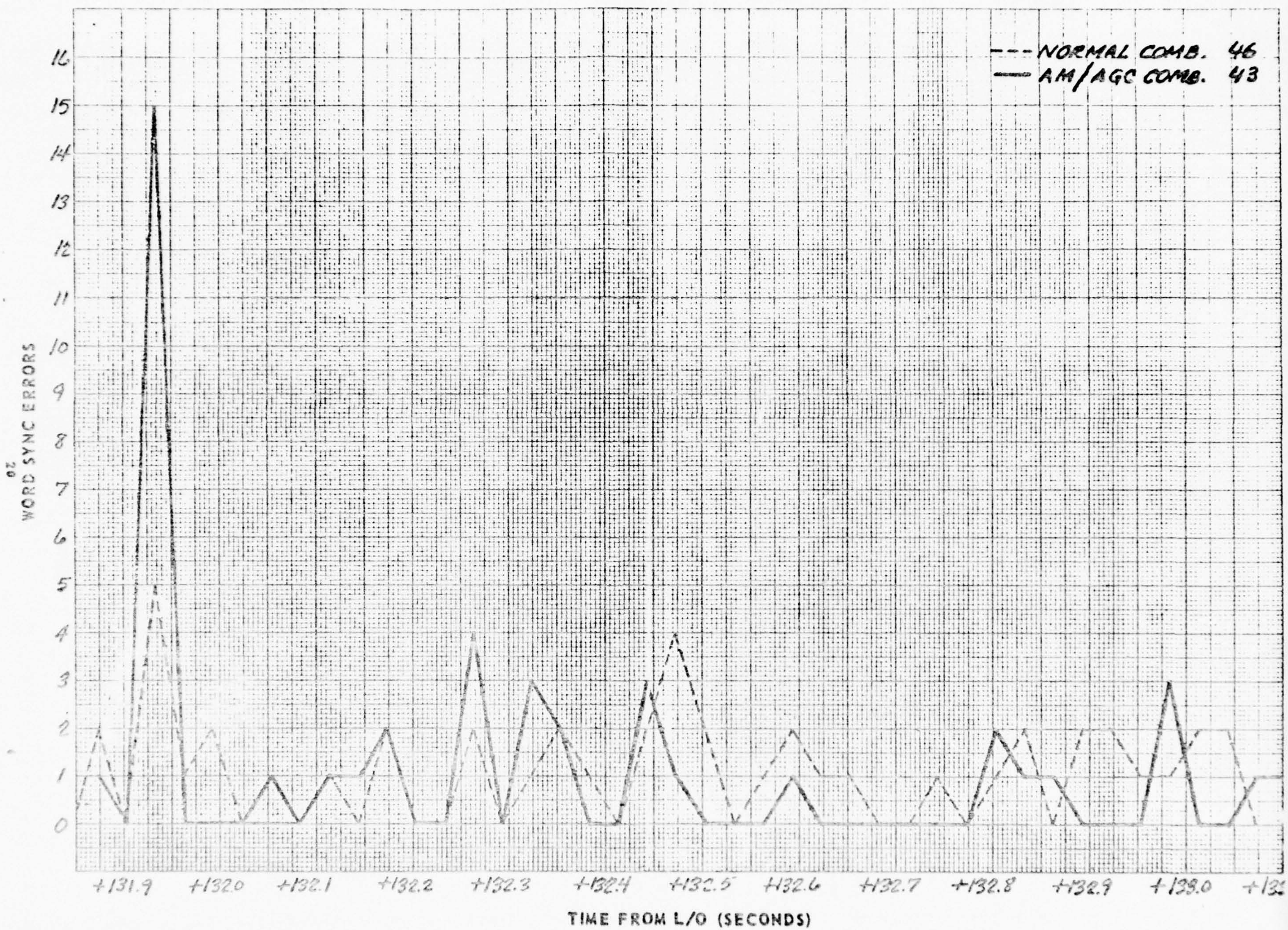
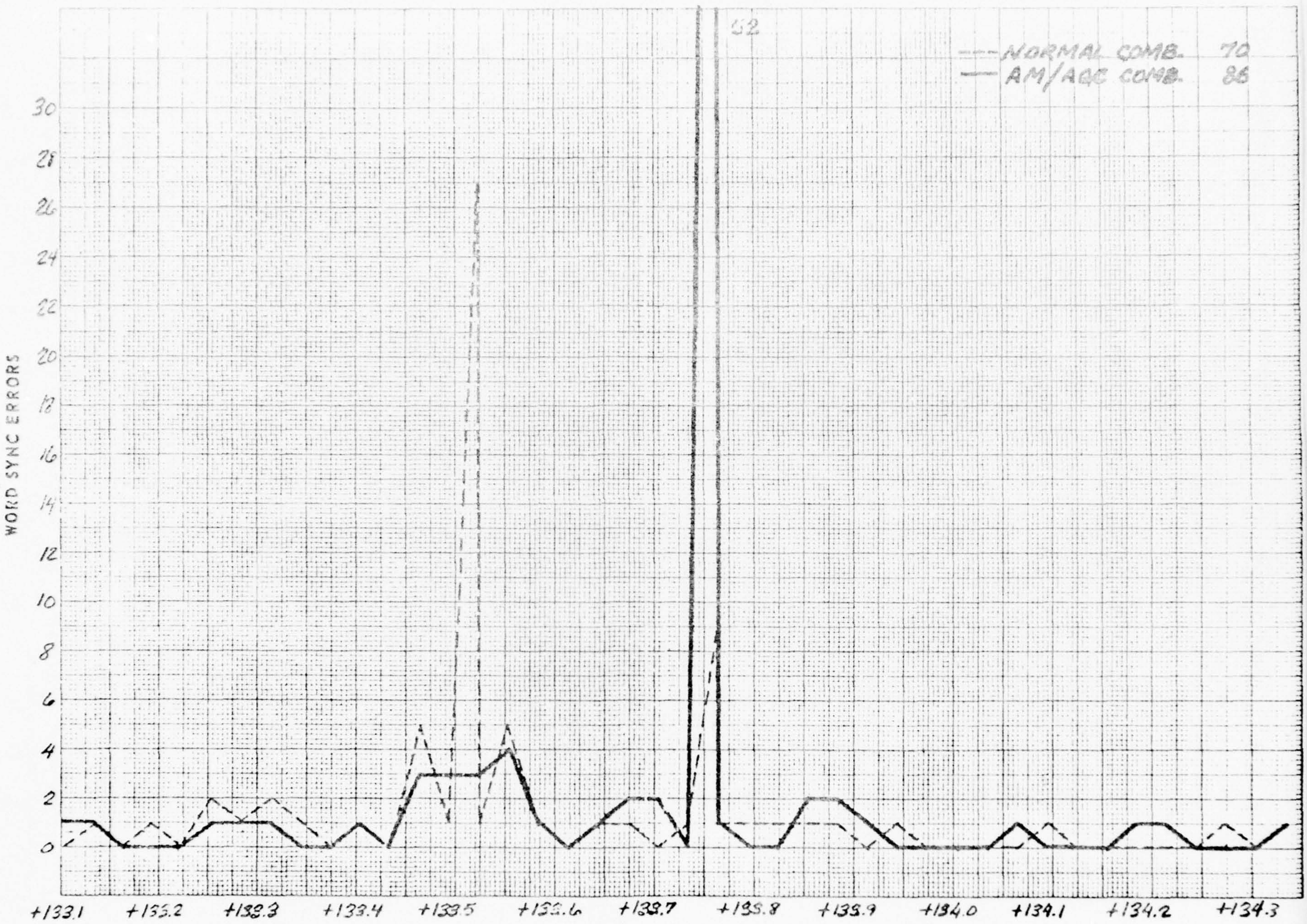


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (4 OF 23)

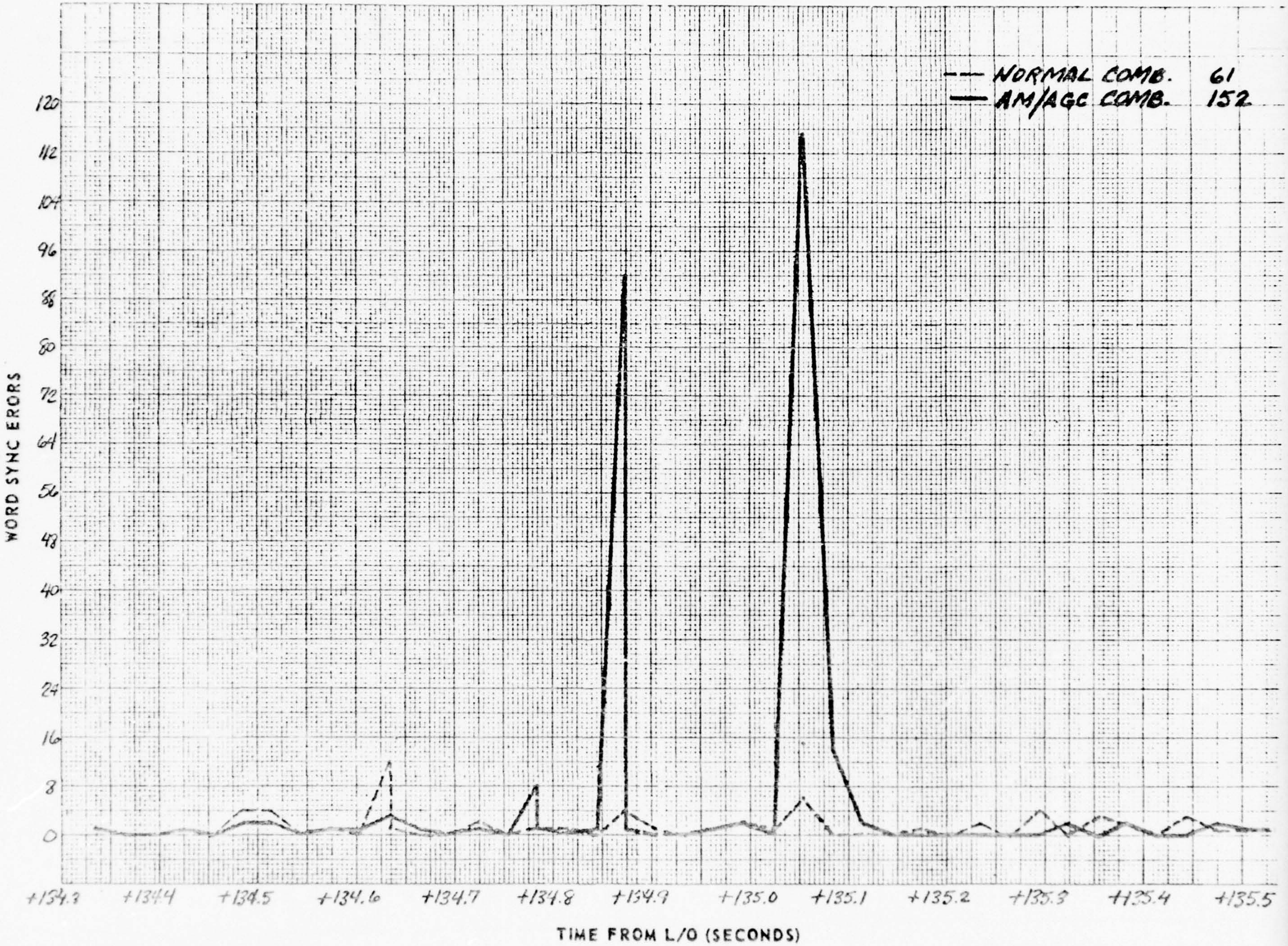


--- NORMAL COMB. 46
— AM/AGC COMB. 43
WORD SYNC ERRORS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
+131.9
+132.0
+132.1
+132.2
+132.3
+132.4
+132.5
+132.6
+132.7
+132.8
+132.9
+133.0
TIME FROM L/O (SECONDS)



TIME FROM L/O (SECONDS)

FIGURE 12 W.S. ERRORS DURING III STAGE BURN (6 OF 23)



--- NORMAL COMB. 61
— AM/AGC COMB. 152
WORD SYNC ERORS
120
112
104
96
88
80
72
64
56
48
40
32
24
16
8
0
+134.3
+134.4
+134.5
+134.6
+134.7
+134.8
+134.9
+135.0
+135.1
+135.2
+135.3
+135.4
+135.5
TIME FROM L/O (SECONDS)

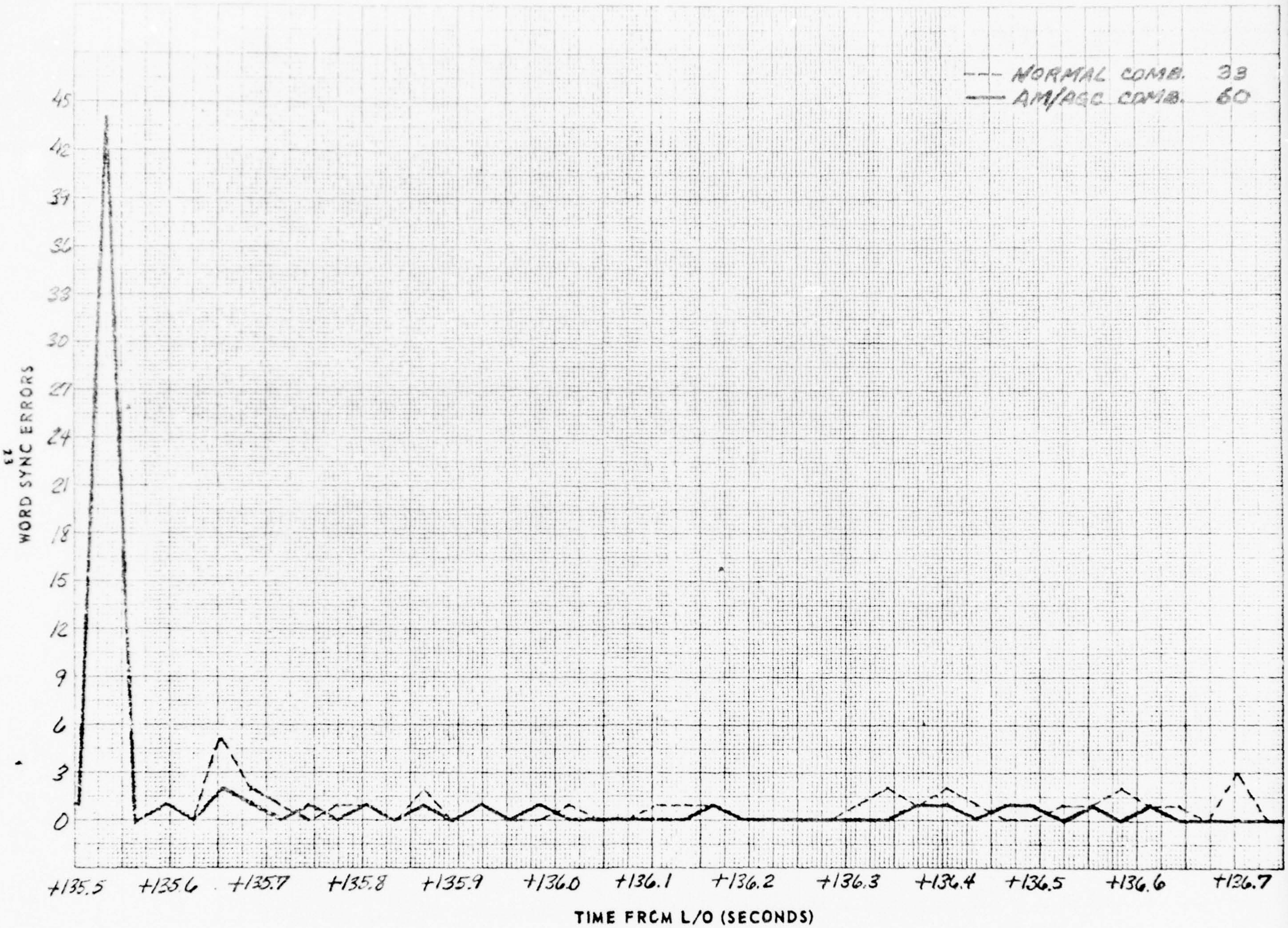
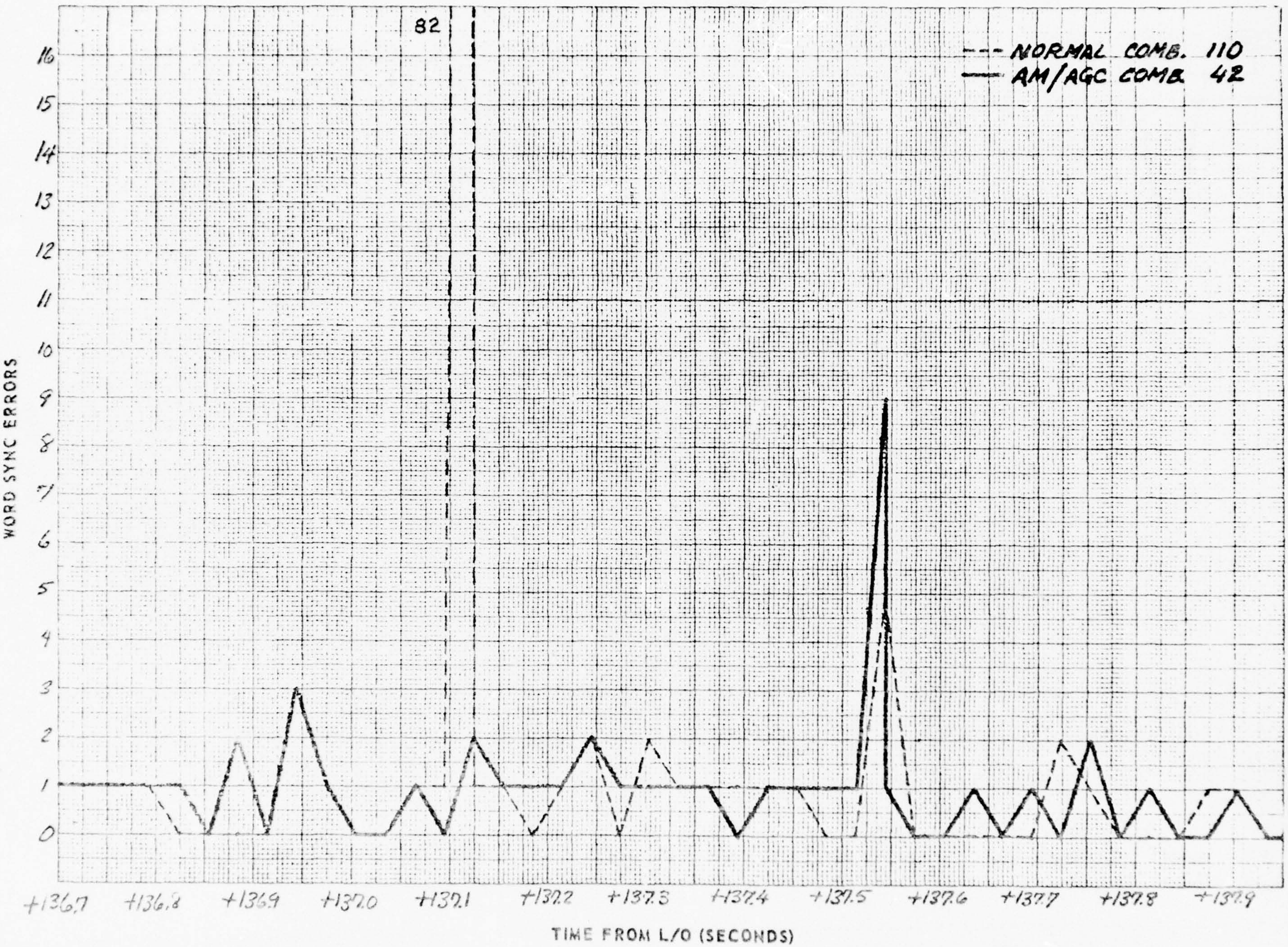


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (8 OF 23)


82
--- NORMAL COMB. 110
— AM/AGC COMB. 42
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
WORD SYNC ERRORS
+136.7
+136.8
+136.9
+137.0
+137.1
+137.2
+137.3
+137.4
+137.5
+137.6
+137.7
+137.8
+137.9
TIME FROM L/O (SECONDS)

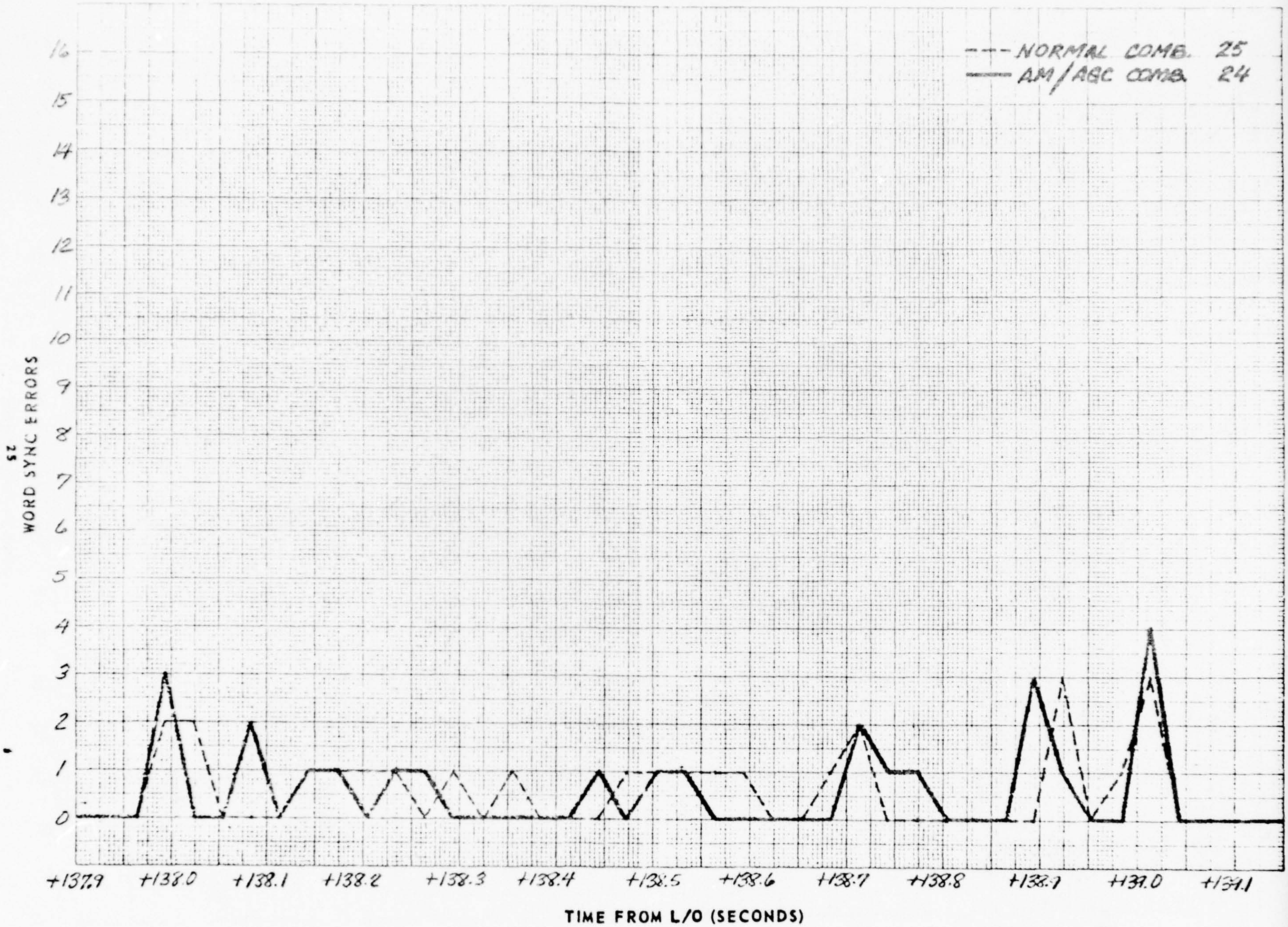
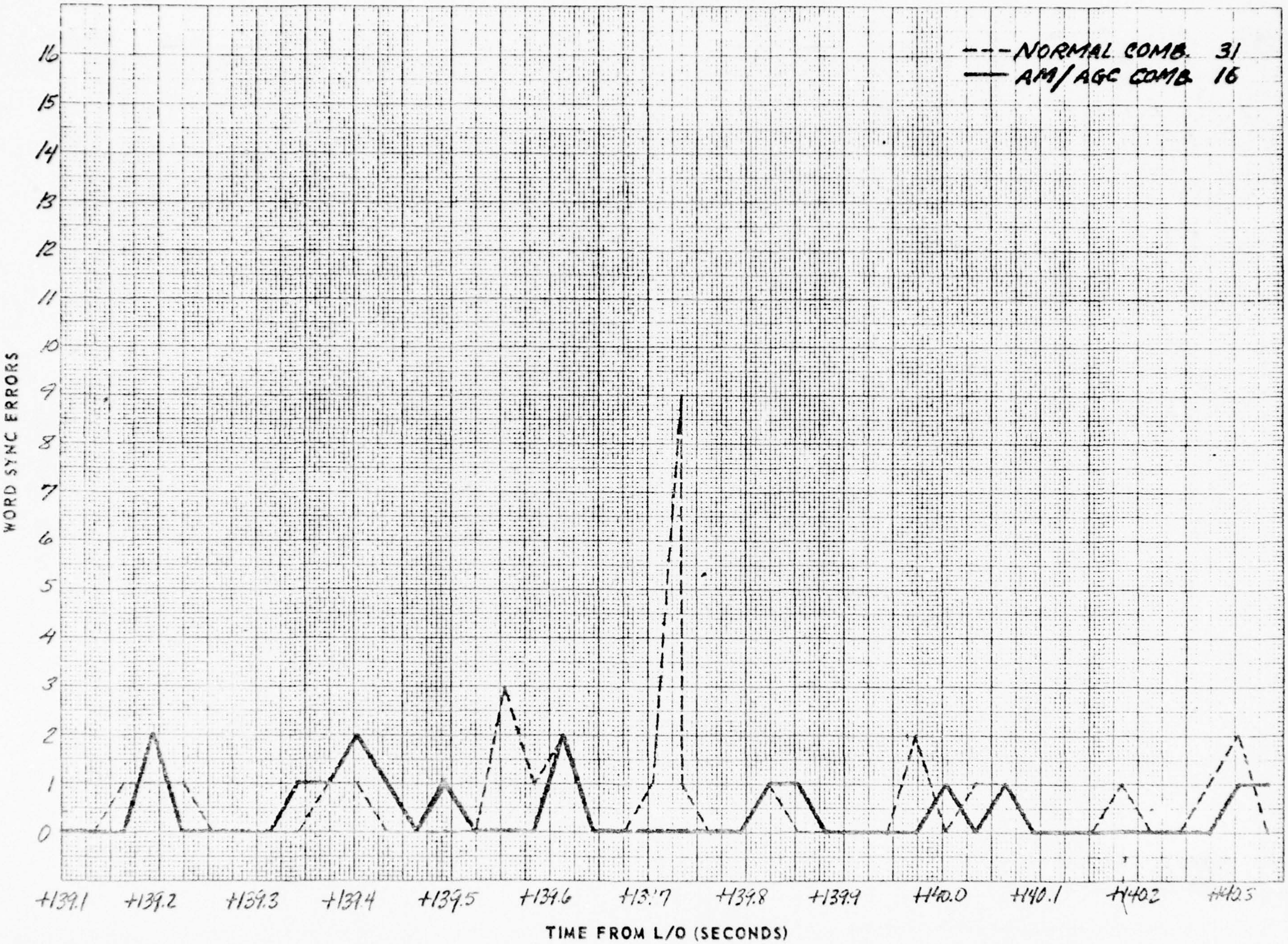


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (10 OF 23)


---NORMAL COMB. 31
— AM/AGC COMB. 16
WORD SYNC ERRORS
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
+139.1
+139.2
+139.3
+139.4
+139.5
+139.6
+139.7
+139.8
+139.9
+140.0
+140.1
+140.2
+140.5
TIME FROM L/O (SECONDS)

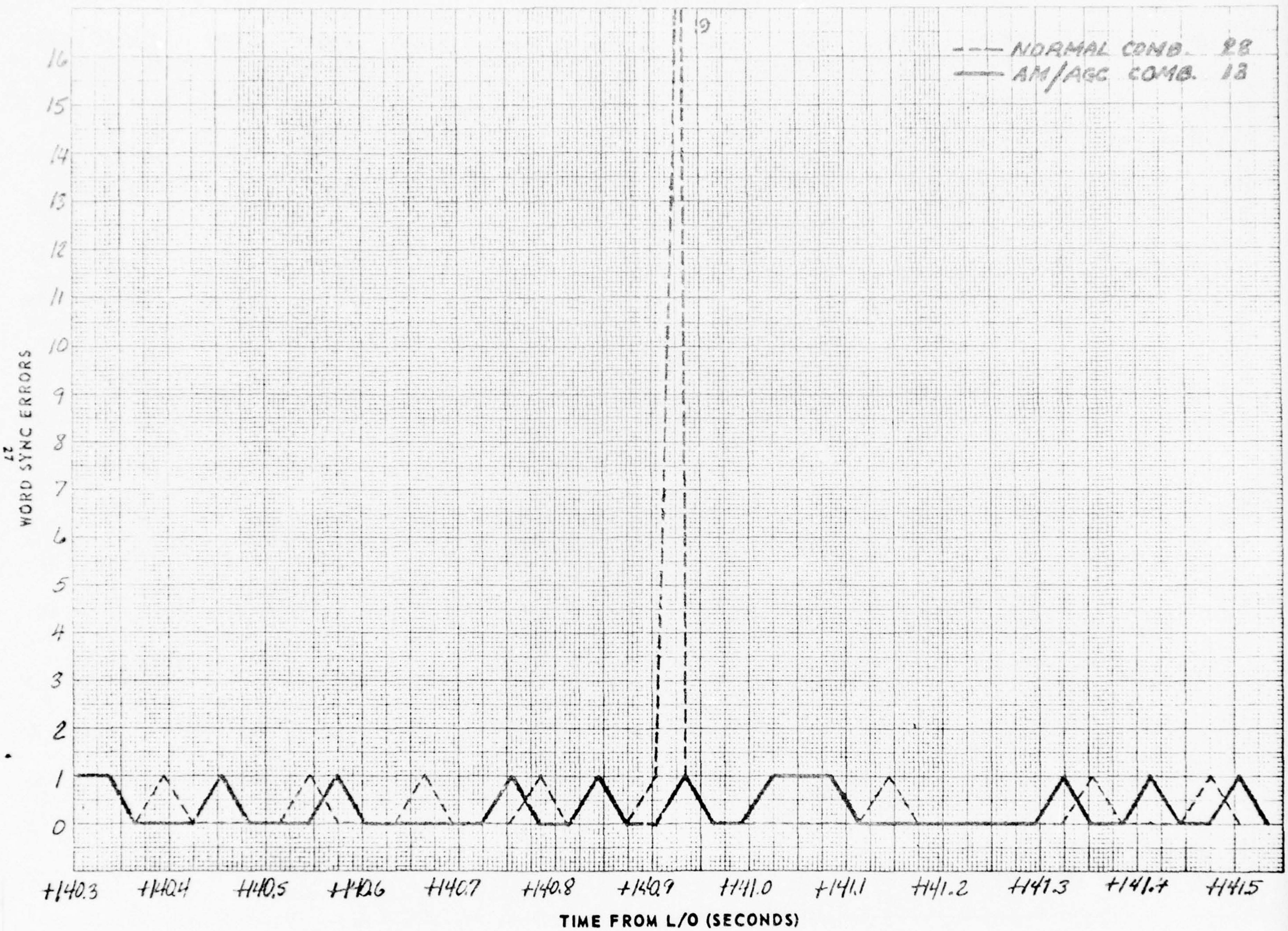
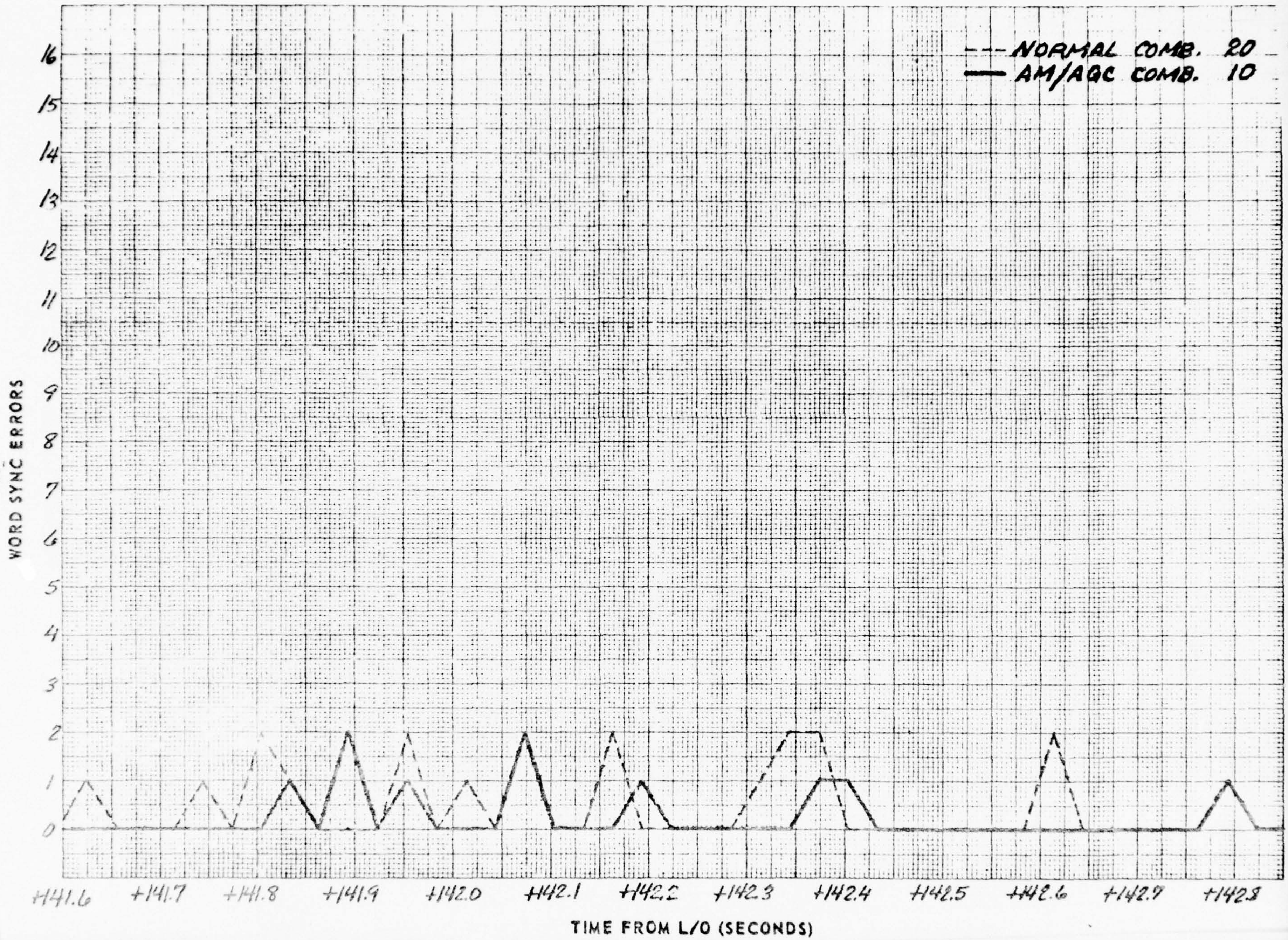


FIGURE 12 W.S. ERROR DURING III STAGE BURN (12 OF 23)


---NORMAL COMB. 20
—AM/AGC COMB. 10
WORD SYNC ERRORS
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
+141.6
+141.7
+141.8
+141.9
+142.0
+142.1
+142.2
+142.3
+142.4
+142.5
+142.6
+142.7
+142.8
TIME FROM L/O (SECONDS)

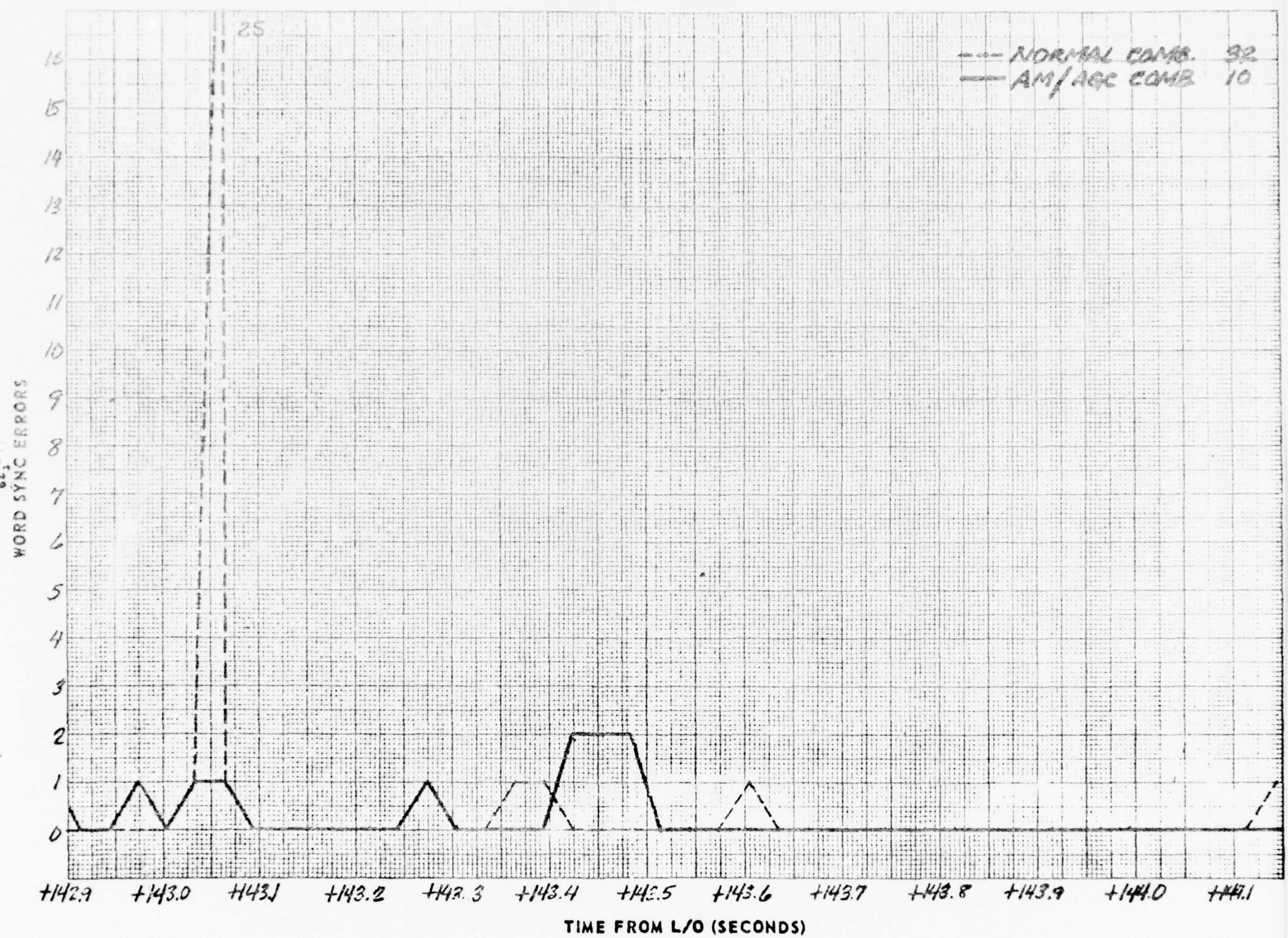
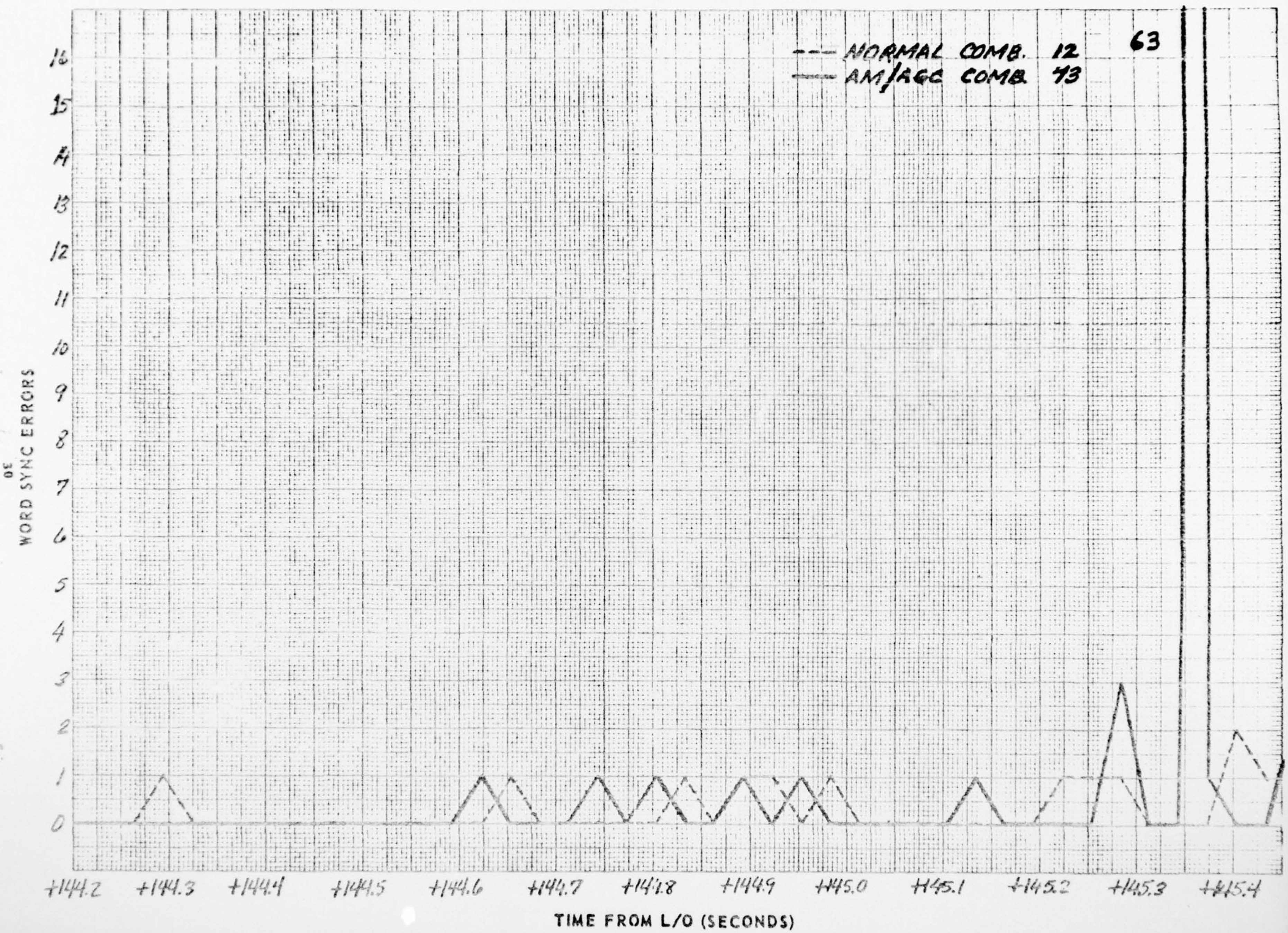


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (14 OF 23)



--- NORMAL COMB. 12
— AM/AGC COMB 43
63
WORD SYNC ERRORS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
+144.2
+144.3
+144.4
+144.5
+144.6
+144.7
+144.8
+144.9
+145.0
+145.1
+145.2
+145.3
+145.4
TIME FROM L/O (SECONDS)

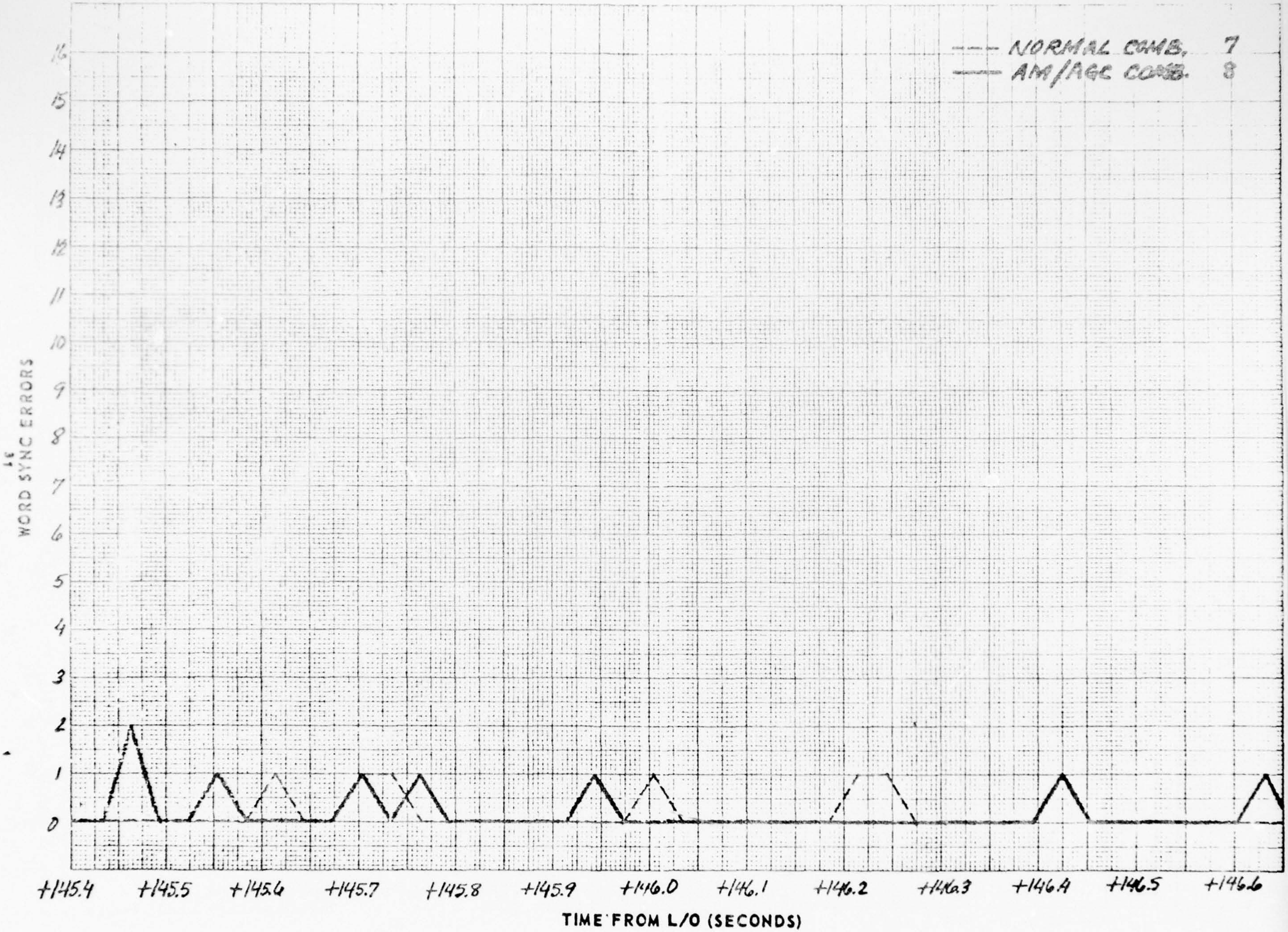
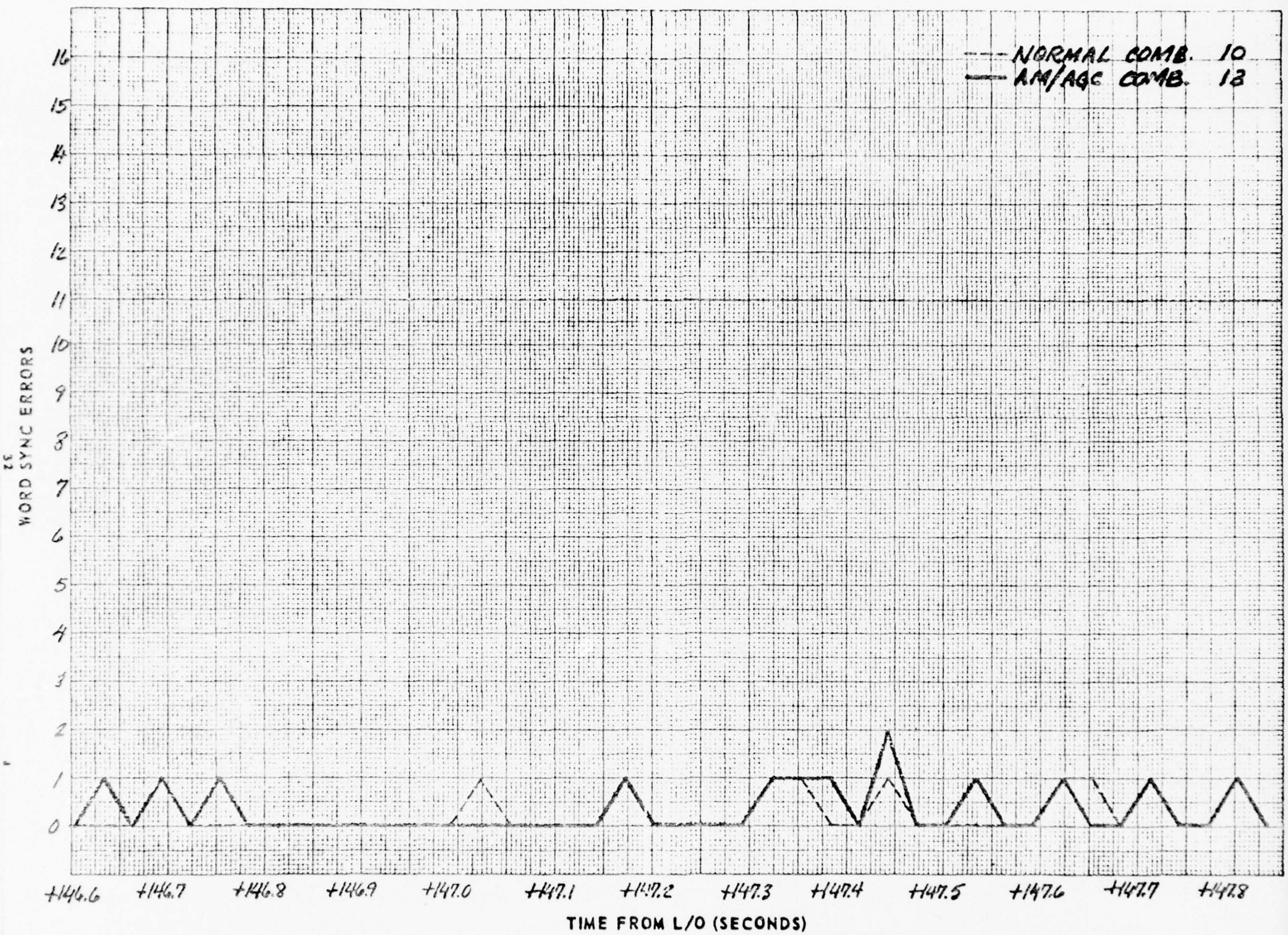


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (16 OF 23)



WORD SYNC ERRORS
16

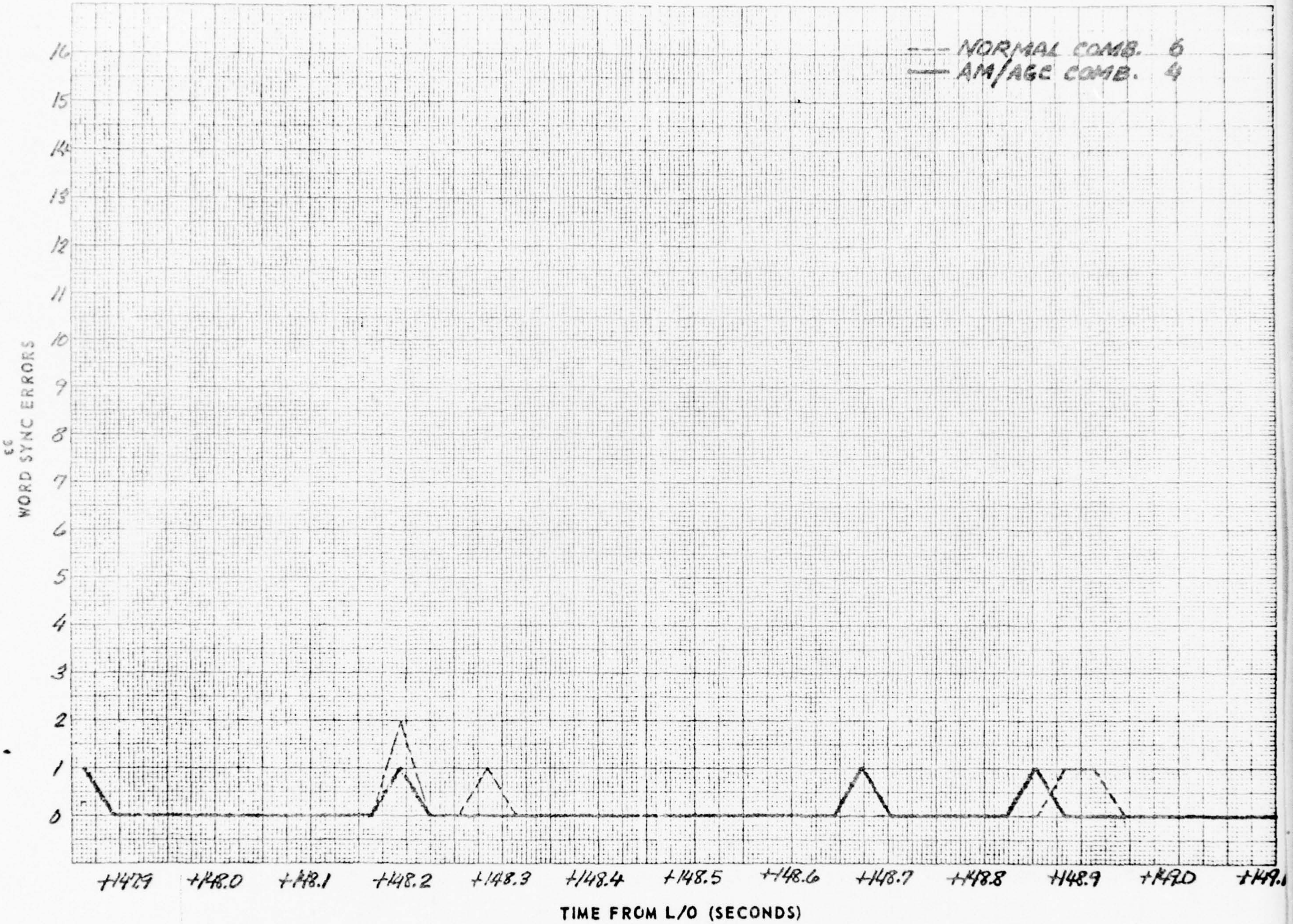
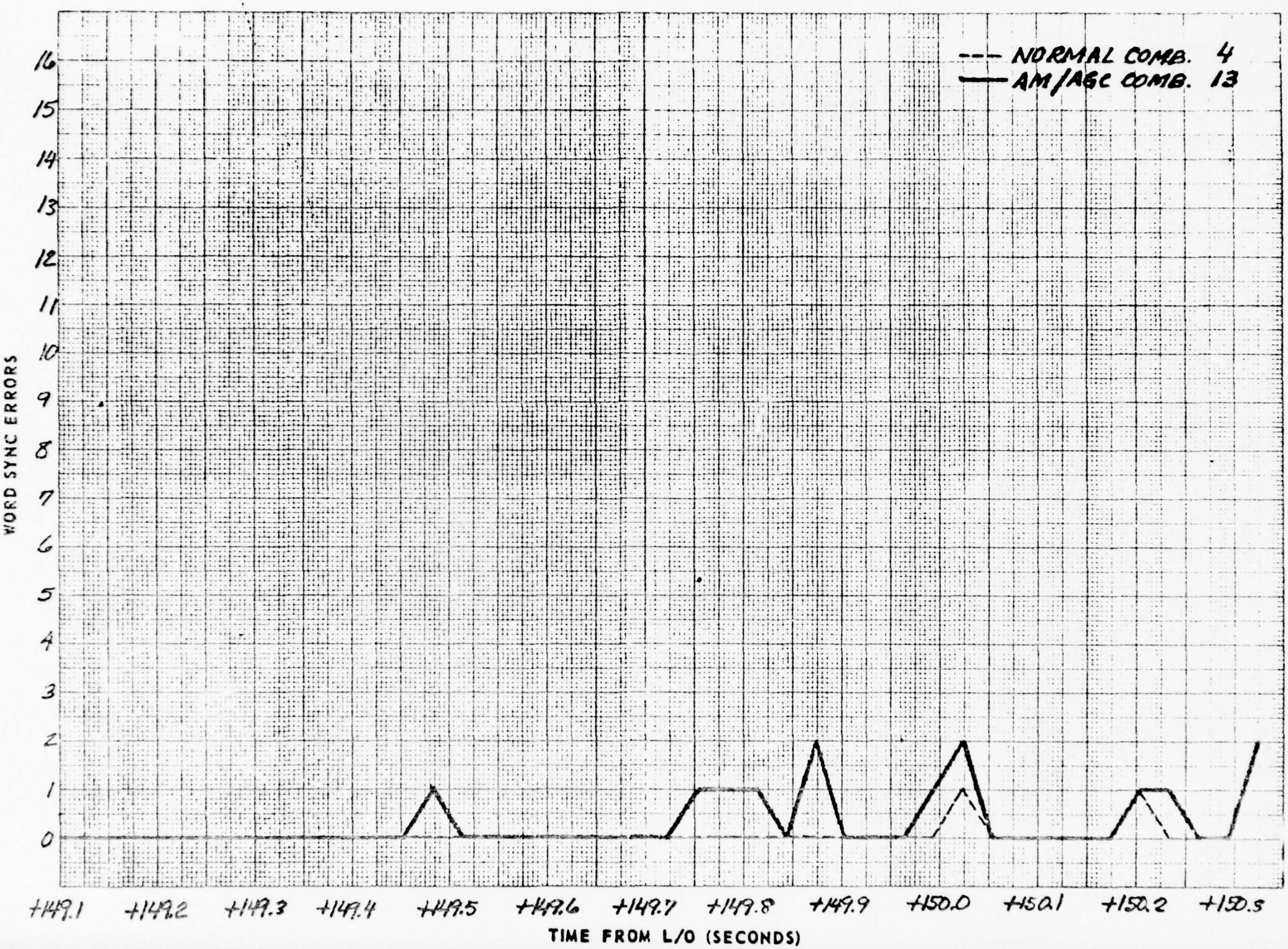


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (18 OF 23)



--- NORMAL COMB. 4
— AM/AGC COMB. 13
WORD SYNC ERRORS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
+149.1
+149.2
+149.3
+149.4
+149.5
+149.6
+149.7
+149.8
+149.9
+150.0
+150.1
+150.2
+150.3
TIME FROM L/O (SECONDS)

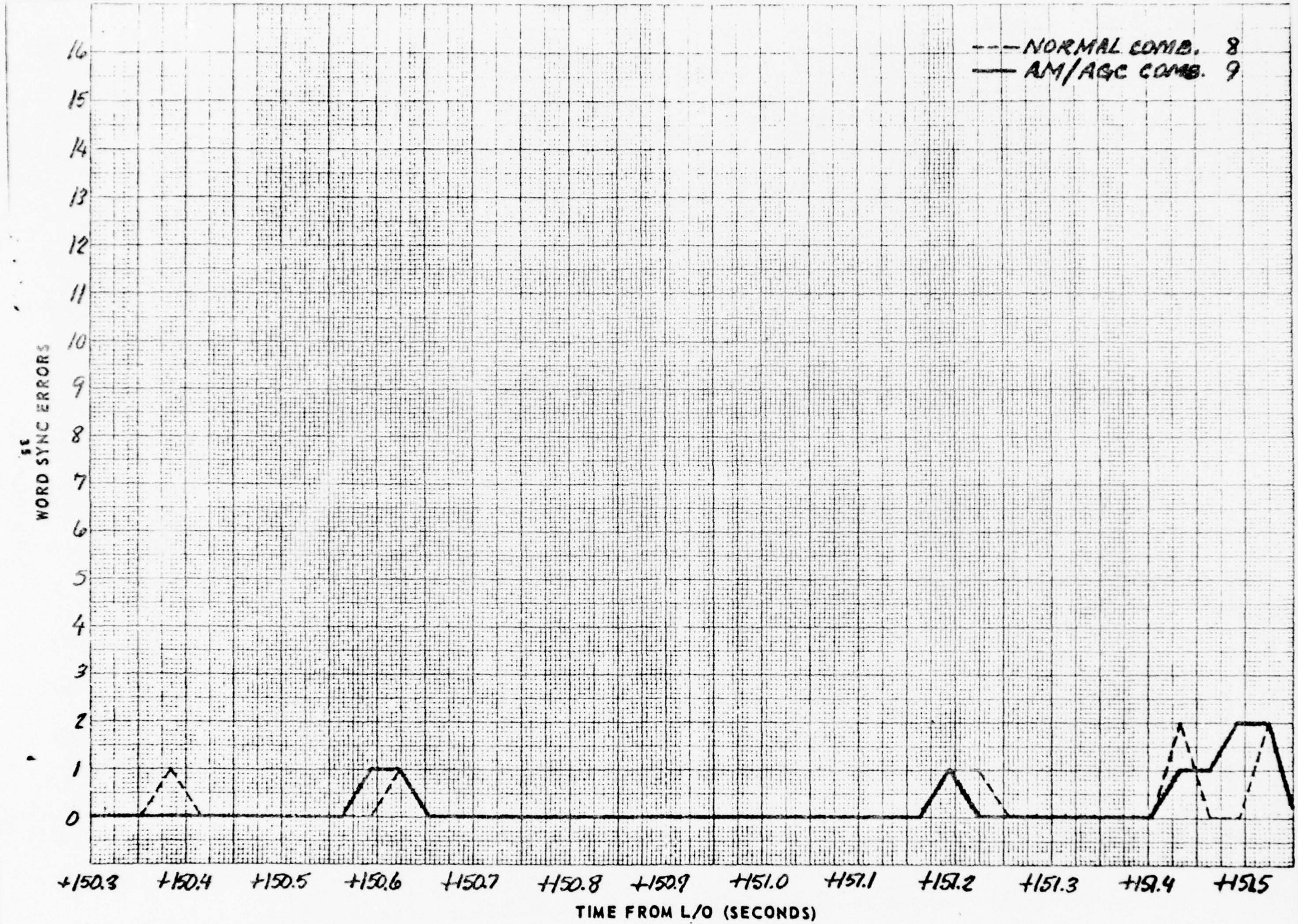
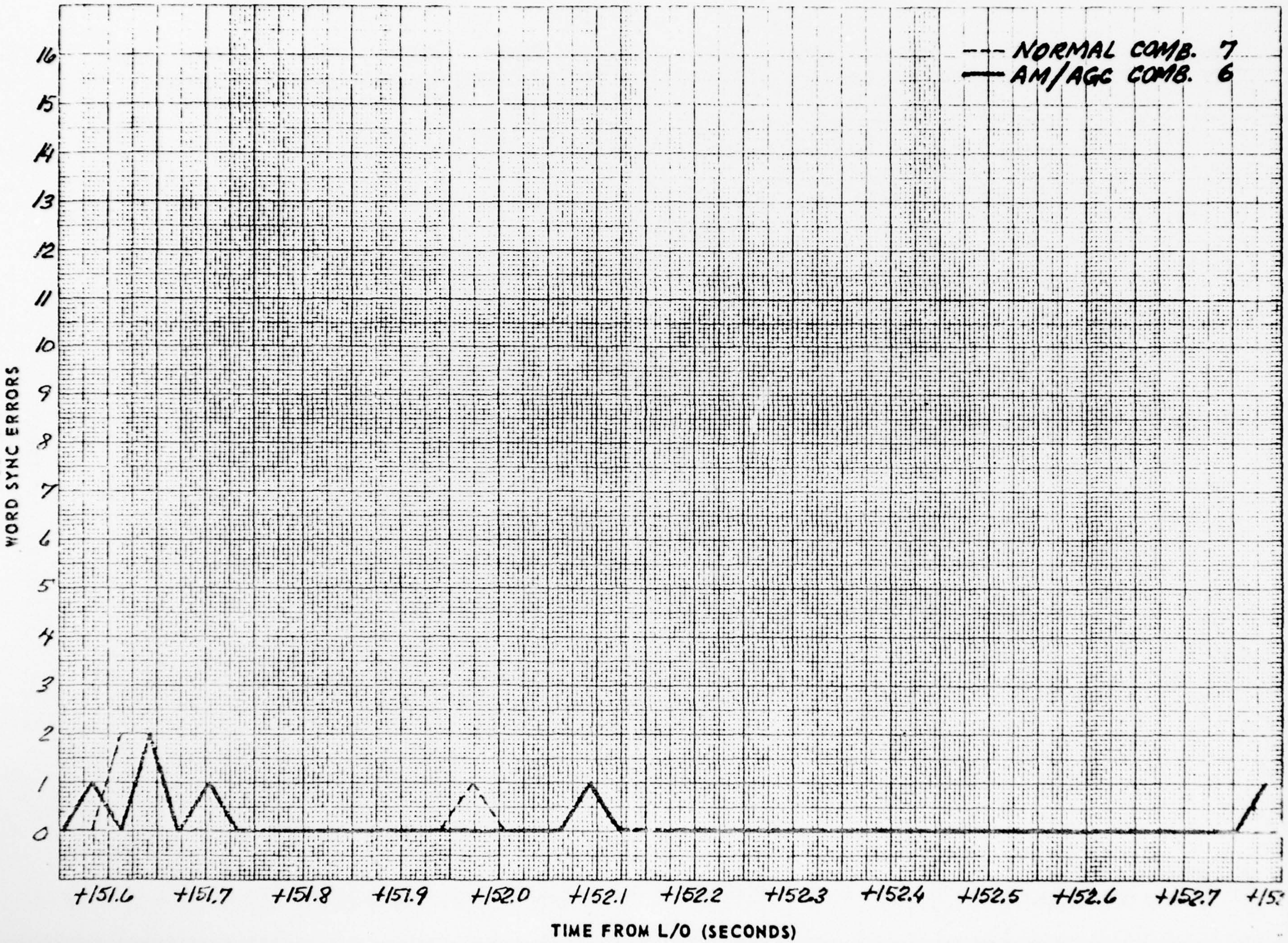


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (20 OF 23)


NORMAL COMB. 7
AM/AGC COMB. 6
WORD SYNC ERRORS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
+151.6
+151.7
+151.8
+151.9
+152.0
+152.1
+152.2
+152.3
+152.4
+152.5
+152.6
+152.7
TIME FROM L/O (SECONDS)

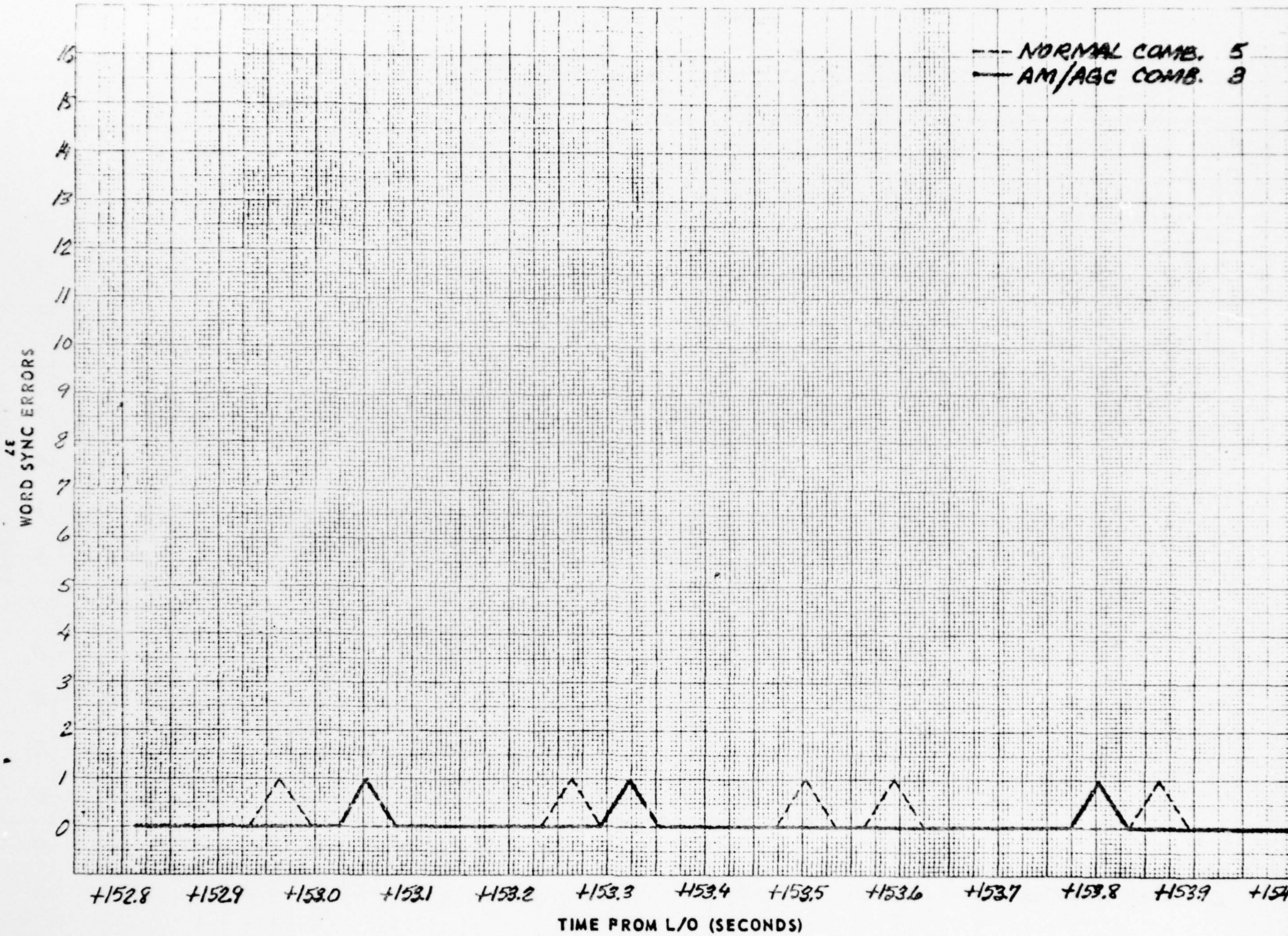
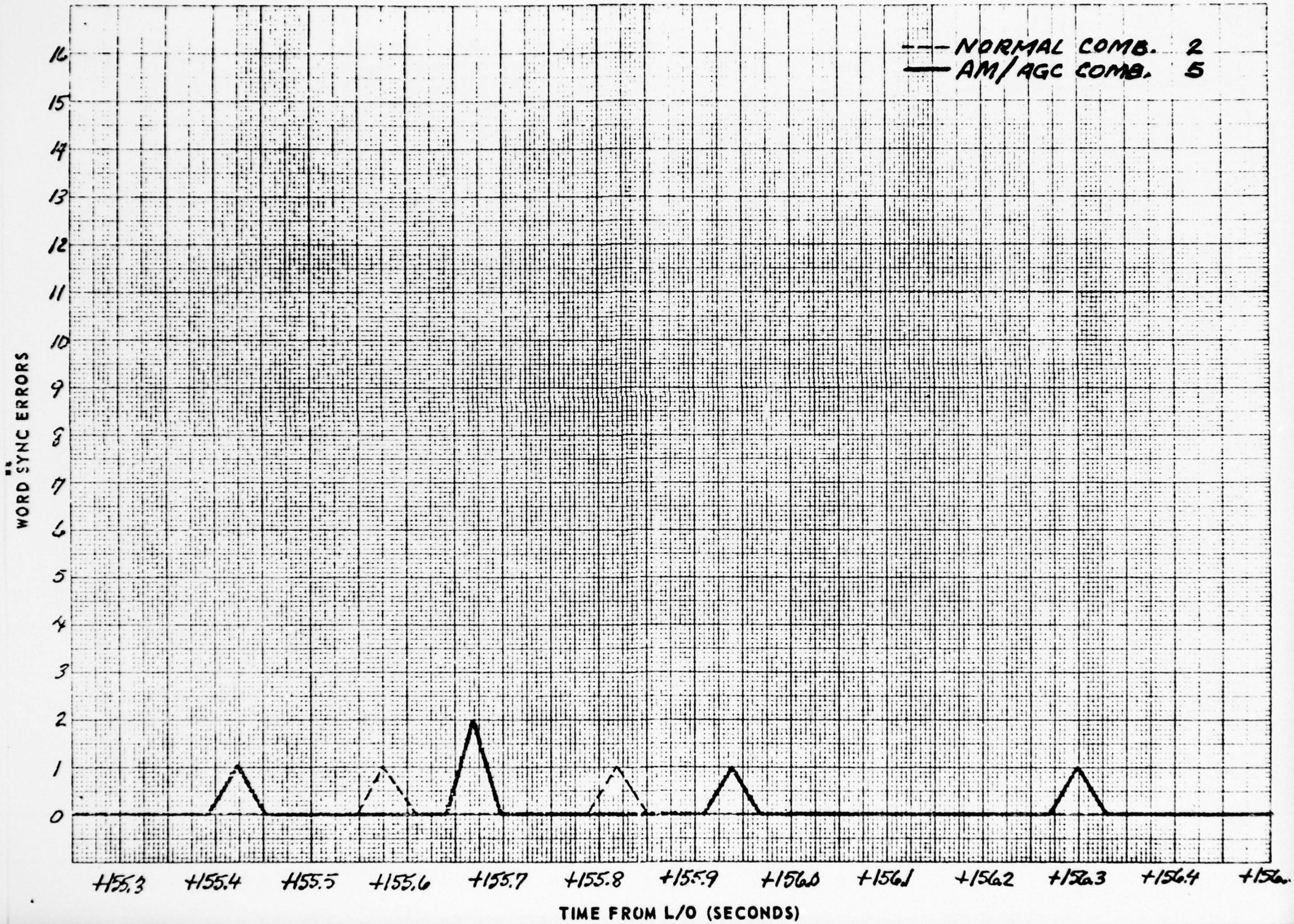


FIGURE 12 W.S. ERRORS DURING III STAGE BURN (22 OF 23)



NORMAL COMB. 2
AM/AGC COMB. 5
WORD SYNC ERRORS
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
+155.3
+155.4
+155.5
+155.6
+155.7
+155.8
+155.9
+156.0
+156.1
+156.2
+156.3
+156.4
TIME FROM L/O (SECONDS)

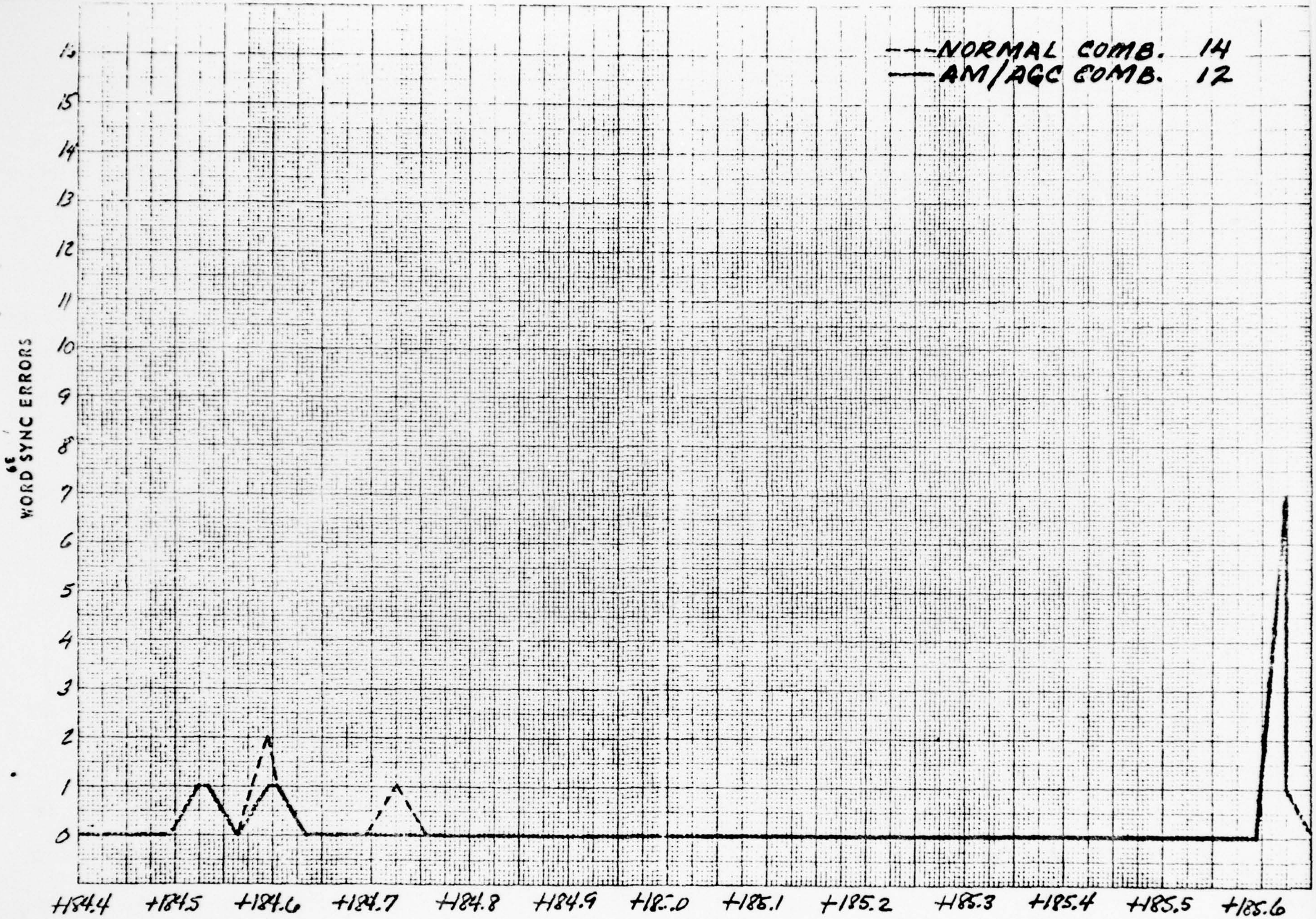


FIGURE 13 W.S. ERRORS AT T.T.

3.2.2 Launch Operation 8230

This Minuteman II launch Operation on 22 June 1976 provided 15 seconds of recorded magnetic tape predetection combined signals from the "select" and "combine" AGC controlled outputs from the AM/AGC Receiver Combiner Interface Unit and a normally configured AGC controlled combiner. Data degradation occurred slightly after lift-off. The DSCU was utilized during this operation to produce a second magnetic tape of the signals measuring phase difference between the right hand circular polarized and left hand circular polarized channels plus individual amplitude measurements of each channel. Dubs of both tapes were sent to PMTC for evaluation.

The useable Minuteman data format was PCM, Bi-ϕ-L/PM. The PCM frame sync (FS) pattern is 27 bits long at a repetition rate of 30 msec. The word sync (WS) pattern is 3 bits long at a repetition rate of 78 μsec. Computer scans of every WS pattern were made to determine the time and number of patterns in error. The WS errors are plotted in Figure 14. Figure 15 shows the Data Source Selector (DSS) valid/invalid bits displayed on a strip chart that were used as a visual comparison between the "combine" AGC controlled combiner and the normal AGC controlled combiner. The DSS display of valid/invalid bits is accomplished by comparing the phase of the data bits to clock time. It looks at a total of 64 bits and if it sees 16 bits out of phase it produces an invalid bit output.

Figure 14 shows that the AM/AGC controlled combiner provided more data near lift-off than the normal AGC controlled combiner. The large errors seen at L+1.75 seconds are suspect and could be the result of the combiner PLL not being locked when the channel was selected.

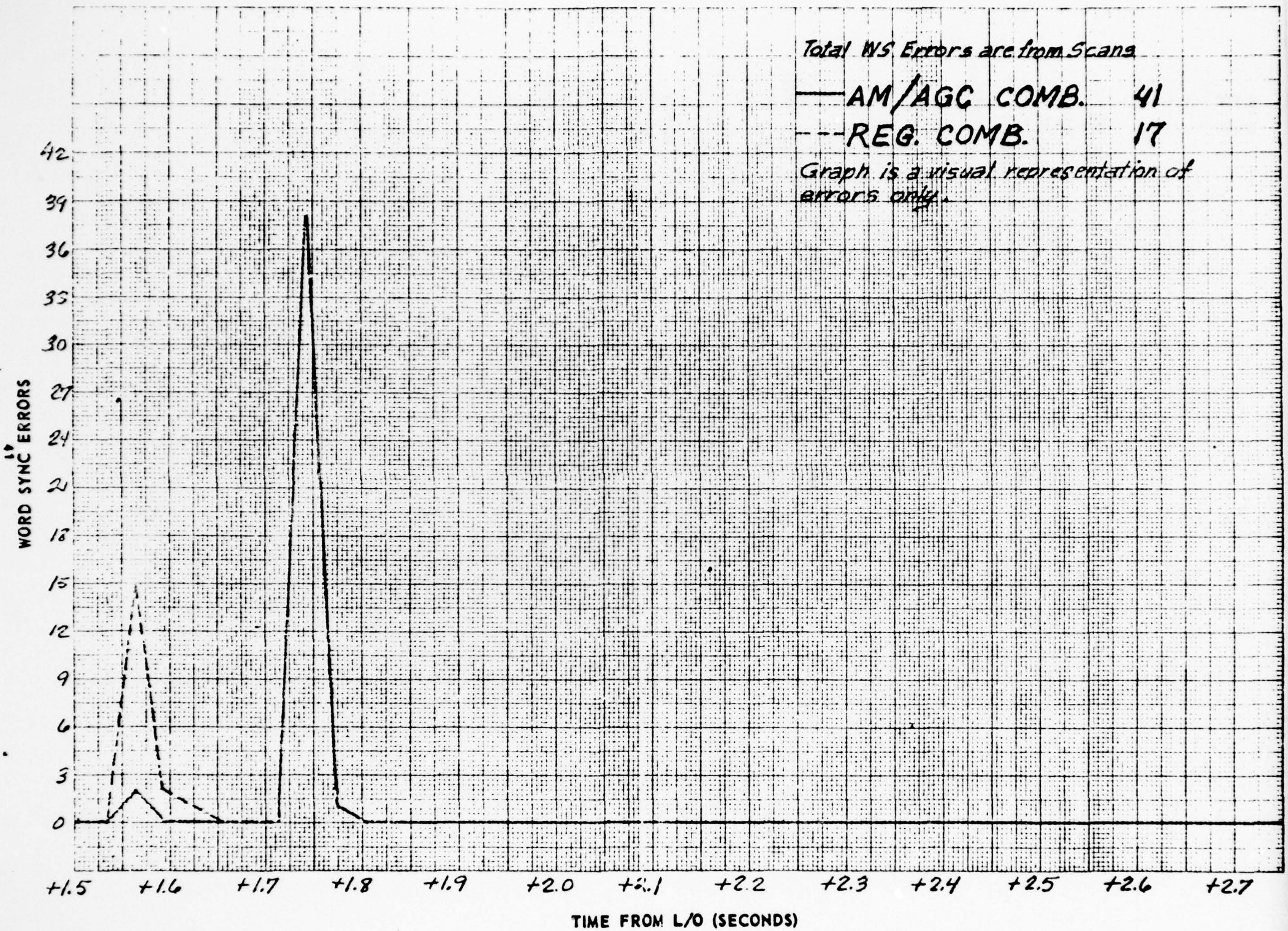


FIGURE 14 W.S. ERRORS NEAR L/O

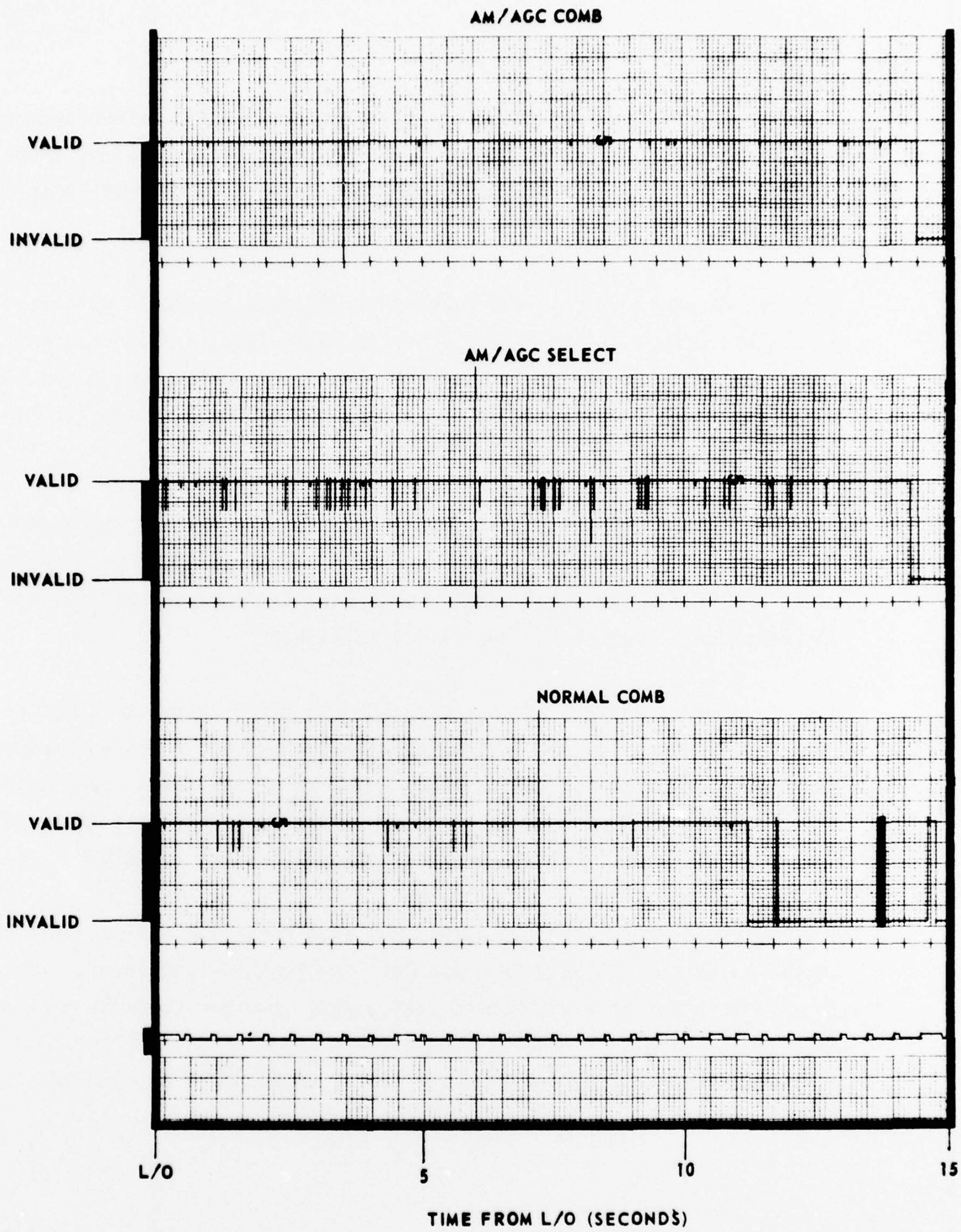


FIGURE 15 VALID/INVALID DSS COMPARISON FOR OPERATION 8230

4.0 CONCLUSIONS

4.1 The AM/AGC Receiver Combiner Interface technique provided data improvement in the recovery of data over the normal AGC controlled combiner technique during the periods of heavy mulitpath interference on the Minuteman launch operations analyzed.

4.2 The Microdyne Model 1100-R receiver AGC gain increases whenever RF signal levels are decreasing towards the system noise level. This reverse AGC character tends to defeat the combiner control technique which uses AGC since the signals being summed are not at the expected levels for control weighting.

4.3 The best receiver AGC time constant setting used with the AM/AGC Receiver Combiner Interface Unit "combine" output is 1 second. The best receiver AGC time constant setting when used with AM/AGC Receiver Combiner Interface Unit "select" output is 0.1 millisecond.

4.4 Fade rates above 1 KHz using either the AM/AGC Receiver Combiner Interface "select" output or the "combine" output could not be measured. A BER improvement was noted at about 2 KHz above the first break point. Fade rates of 20 KHz could be obtained. This indicates that there could be a problem with the Combiner PLL noise bandwidth being too tight.

4.5 As the primary problems associated with combining during rapid fades appear to be associated with phaselock loop response and acquisition of lock, it is possible that a high speed post detect combiner could be utilized to advantage. FM plus integrate demodulators could be used in the receiver so that all phase lock loops in the signal chain would be eliminated.

APPENDIX A

"Diversity Combiner Improvement Phase II"

E. R. Hill

5 April 1976

PMTC

DIVERSITY COMBINER IMPROVEMENT - PHASE II

E. R. Hill
5 April 1976

Pacific Missile Test Center

Phase I of this effort is outlined in the report, "AM/AGC Receiver-Combiner Interface" dated 25 November 1974 and in an addendum to this dated 27 January 1975. This report describes a continuation of this effort and is also written as a continuation of the Phase I report.

Modifications have been made as recommended by SAMTEC in their evaluation report "Diversity Combiner AM/AGC Control Technique," PA100-75-45. Three changes were made to reduce the reponse time of the weighting signals. First, the bandwidth of the AM detector LPF was increased from 30 kHz to 100 kHz. (Increase in this bandwidth imposes a compromise between weighting signal response time and noise rejection. Indications are that the best trade off is no more than 100 kHz and maybe less.) Second, the Analog Devices 755N log amp was replaced with the wider band Teledyne Philbrick 4350 log amp. Third, the log amp reference current was increased from 10 μA to 100 μA. The increase in reference current required the potentiometer and fixed resistor preceding the log amp to be reduced to 10k and 5k respectively, an order of magnitude below their former values. To eliminate the overshoot of the weighting signal it was necessary to resort to an RC LPF (exponential step response) since it was found that even the small overshoot of a linear phase filter was greatly magnified by the log amp. The details of the AM detector and LPF are shown in Figure 4 which is the same as Figure 2 except for the modifications.

Also included in the Phase II effort is circuitry for selecting the receiver channel with the greater RF input signal level $_s$ and thus greater SNR. The 1973 ITC paper (page 485) suggested that an optimum diversity selector could be constructed by implementing equation (37). This can be done with a practical circuit as follows. Equation (37) can be rewritten in the form

$$\log K_2 e_s = \log \left(\frac{e_a}{V}\right) - \frac{e_g}{K_1} . \qquad (6)$$

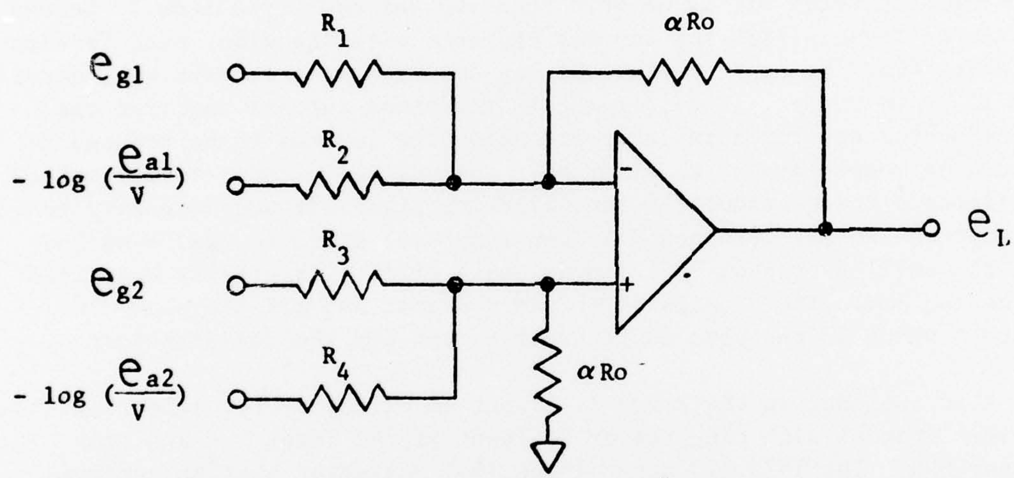
by rearranging and taking the log of each side. When (6) is expressed for each receiver and the two equations are subtracted an equation of the following form is obtained

$$e_L = \log\left(\frac{e_{s1}}{e_{s2}}\right) = -\frac{e_{g1}}{K_1} + \log\left(\frac{e_{a1}}{V}\right) + \frac{e_{g2}}{K_1} - \log\left(\frac{e_{a2}}{V}\right) \quad (7)$$

Equation (7) shows that a linear combination of the signal voltages e_g and $-\log \frac{e_a}{V}$ for the two receivers can produce a signal which is equal to the log of the ratio of the RF signal levels of the two receivers. It is also noted that these signal voltages already exist in the interface chassis as part of the AM/AGC weighting circuitry. From equation (16) of the ITC paper it is seen that for two identical receivers.

$$\frac{SNR_1}{SNR_2} = \frac{e_{s1}}{e_{s2}} \quad (8)$$

The signal expressed by (7) has two desirable characteristics for a selector signal. First, the log function helps to compress the dynamic range and second the output e_L will be zero when e_{s1} and e_{s2} are equal, positive when e_{s1} is greater than e_{s2} and negative when e_{s1} is less than e_{s2}. In terms of the following op amp differential summing circuit.



equation (7) can be written in the form

$$e_L = \alpha\left[-\frac{Ro}{R_1} e_{g1} + \frac{Ro}{R_2} \log\left(\frac{e_{a1}}{V}\right) + \frac{Ro}{R_3} e_{g2} - \frac{Ro}{R_4} \log\left(\frac{e_{a2}}{V}\right)\right] \quad (9)$$

where it is seen by comparing (7) and (9) that

$$
\begin{aligned}
R_1 &= K_1 \, Ro \\
R_2 &= Ro \\
R_3 &= K_1 \, Ro \\
R_4 &= Ro
\end{aligned}
\qquad (10)
$$

where α is a linear gain factor which determines the sensitivity of the output e_L which can now be expressed by

$$e_L = \alpha \log \left(\frac{e_{s1}}{e_{s2}}\right) \qquad (11)$$

A gain factor $\alpha = 10$ has been chosen which sets the sensitivity of e_L at 0.5 volt per dB and this voltage is brought out at the back of the interface chassis for possible monitoring. The resistor values in (10) were determined by letting $K_1 = 2$ and Ro = 4.02K. Inside the interface chassis the signal e_L goes to a comparator with threshold levels set at $\pm$ 3V which means that it will change state when the RF signal level of either channel exceeds the other by 6 dB or more. The threshold detector output is converted into two bilevel output signals of approximately -2V and -4V. When applied to the control inputs of the 3300C combiner these signals cause one receiver output to be selected and the other to be rejected. These control signals are designated AGC_1 select and AGC_2 select on the back panel of the interface chassis. The control signals for AM/AGC combining are now designated AGC_1 combine and AGC_2 combine. The optimum selection circuitry appears in Figure 5 in addition to the previously existing circuitry of Figure 1. The internal resistors in series with the op amp output terminals have been increased from 51 Ω to 470 Ω to provide short circuit protection. This is possible since the AGC input impedances of the 3300C are high. The bandwidths will not be adversely affected by cable lengths up to about 30 feet.

The set-up procedure is repeated here for convenience. When using the "AM/AGC Receiver-Combiner Interface" the adjustment procedures for the 2200R and 3300C beginning on page 3-4 of the 3300C manual can be used with the following modifications:

Receiver Adjustments

(3-9)c The AGC voltages can be read on the DPM provided on the front panel of the "AM/AGC Receiver-Combiner Interface" chassis. The AGC voltage should be approximately -1V for an IF SNR of 0 dB. Common 2nd LOs are not necessary.

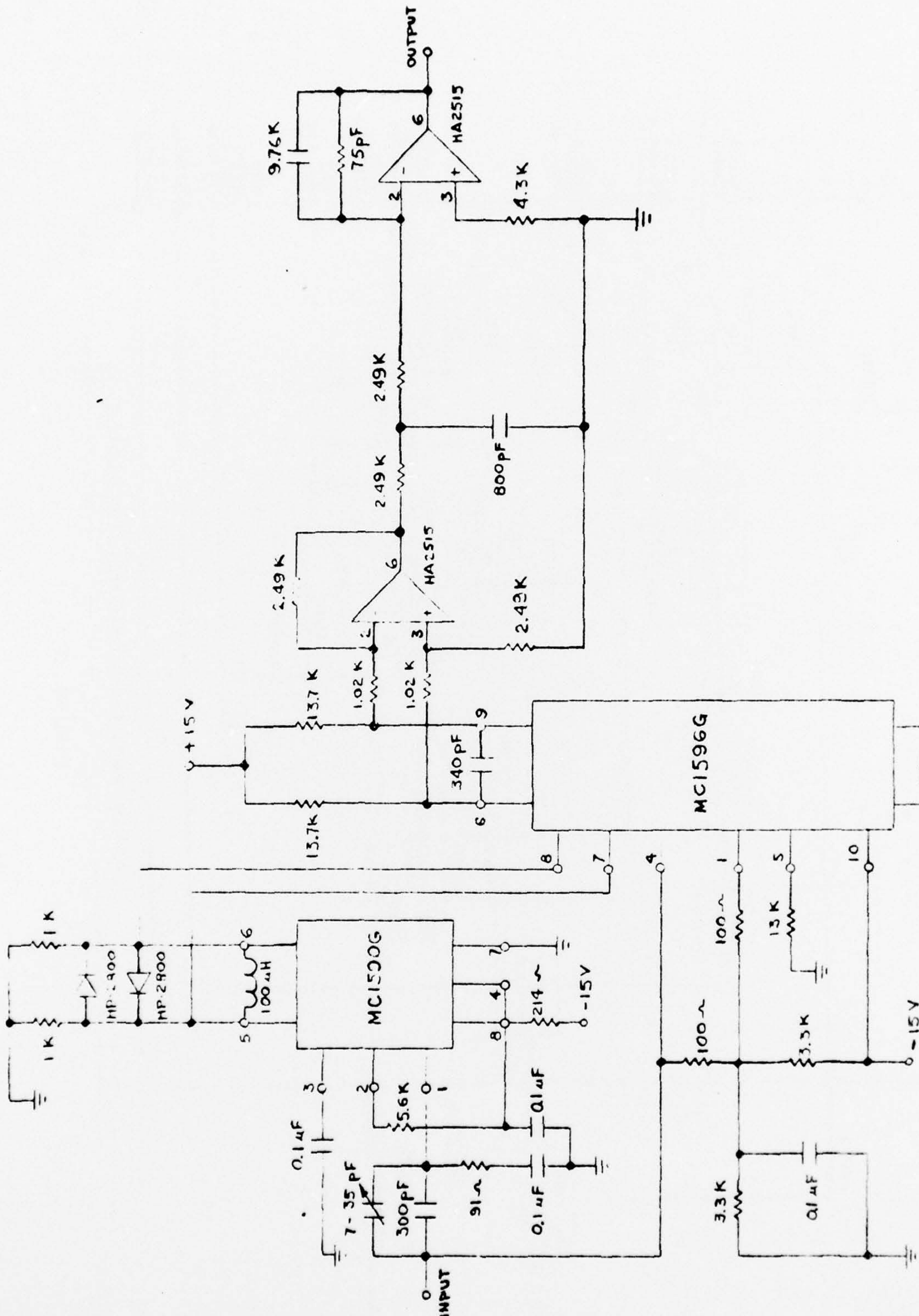
(3-9)d The linear IF signal levels at the inputs to the interface chassis should be between 30 and 100 mV RMS with the nominal at 50 MV RMS. The AGC slope must be set for 100 MV/dB over the region of operation. One suggestion is to adjust the "scale" control for a 1.0 volt change in AGC voltage for a change in IF SNR from +6 dB to +16 dB.

(3-9)f Use linear IF outputs.

Combiner Adjustments

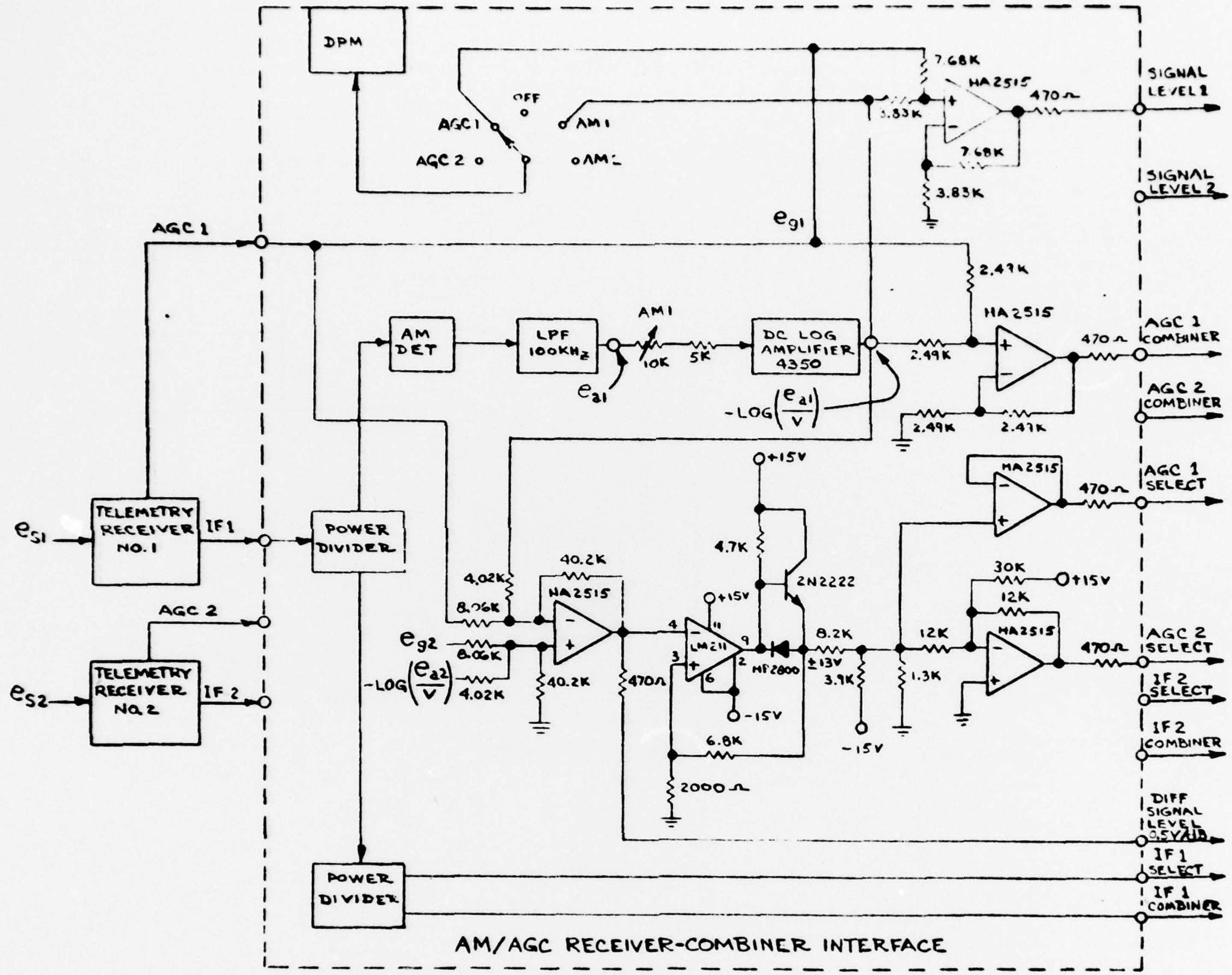
(3-10)c Set switch to "logic disable."

In the Phase III effort it is planned to convert the interface chassis into a complete AM/AGC Combiner/Selector by including frequency translation to tape carrier, phase-lock-loop and combiner circuitry. The phase-lock-loop configuration will be based on results of a current investigation into the best PLL characteristics for pre-D combiner applications.



OUTPUT
9.76K
75pF
HA2515
4.3K
2.49K
2.49K
800pF
2.49K
HA2515
2.43K
13.7K
1.02K
1.02K
+15V
340pF
13.7K
MC1596G
249Ω
1K
1K
HP2900
HP2900
100μH
MC1590G
214Ω
-15V
0.1μF
5.6K
0.1μF
100Ω
13K
100Ω
3.3K
-15V
7-35pF
300pF
91Ω
0.1μF
3.3K
0.1μF
INPUT

FIGURE 4



DPM
OFF
AGC 1
AGC 2
AM 1
AM 2
7.68K
3.83K
HA2515
470Ω
SIGNAL LEVEL 1
SIGNAL LEVEL 2
AGC 1
e_{g1}
2.49K
AM DET
LPF 100KHz
e_{a1}
AM1
10K
5K
DC LOG AMPLIFIER 4350
$-LOG\left(\frac{e_{a1}}{V}\right)$
2.49K
AGC 1 COMBINER
AGC 2 COMBINER
+15V
AGC 1 SELECT
TELEMETRY RECEIVER NO. 1
IF1
e_{S1}
POWER DIVIDER
4.02K
8.06K
40.2K
4.7K
2N2222
30K
12K
AGC 2
e_{g2}
$-LOG\left(\frac{e_{a2}}{V}\right)$
LM211
MF2800
8.2K
±13V
3.9K
1.3K
-15V
6.8K
2000Ω
TELEMETRY RECEIVER NO. 2
IF 2
e_{S2}
AGC 2 SELECT
IF 2 SELECT
IF 2 COMBINER
DIFF SIGNAL LEVEL
IF 1 SELECT
IF 1 COMBINER
POWER DIVIDER
AM/AGC RECEIVER-COMBINER INTERFACE

FIGURE 5